FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

Department of Energy (DOE)
Office of Fossil Energy and Carbon Management (FECM)

CARBON MANAGEMENT

Funding Opportunity Announcement (FOA) Number: DE-FOA-0002614

FOA Type: Modification 000014

Assistance Listing Number: 81.089 - Fossil Energy Research and Development

FOA Issue Date:	08/13/2024
Submission Deadline for Full Applications:	10/14/2024 / 8:00 PM ET
Expected Date for Selection Notifications:	02/03/2025
Expected Date for Award:	06/18/2025

Round 6: This FOA is being re-opened to solicit applications for new Areas of Interest:

- AOI-1F. Reactive Carbon Capture Approaches for Point Source Capture or Atmospheric Capture with Integrated Conversion to Useful Products
- AOI-3F. Engineering-Scale Testing of Transformational Carbon Capture Technologies for Natural Gas Power Plants (NGPP)
- AOI-3G. Engineering-Scale Testing of Transformational Carbon Capture Technologies in Portable Systems at Industrial Plants
- AOI-3H-a. Preliminary Front-End Engineering and Design Studies (Pre-FEED) for Carbon Capture Systems at Existing (Retrofit) Domestic NGPP
- AOI-3H-b. Preliminary Front-End Engineering Design Studies (Pre-FEED) for Carbon Capture Systems at Hydrogen Production Facilities Using Coal, Mixed Coal/Biomass, or Natural Gas Feedstock
- AOI-4A. Enhancing CO_2 Transport Infrastructure (ECO_2Transport): Pre-FEED Studies for Multimodal CO_2 Transfer Facilities

Complete details for how to apply to this FOA opening are contained herein.

Modifications

Mod. No.	Date	Description of Modification
000001-000003	[redacted]	Modifications associated with Round 1.
000004-000007		Modifications associated with Round 2.
000008-000009		Modifications associated with Round 3.
000010		FOA re-opened for Round 4.
000011	[redacted]	FOA re-opened for Round 5.
000012	08/13/2024	FOA re-opened for Round 6.
000013	08/21/2024	Modifications associated with Round 6.
000014	08/30/2024	This modification is issued to provide clarification on technologies of interest. All changes are highlighted in yellow.

* Applicants are discouraged from submitting information considered proprietary unless it is deemed essential for proper evaluation of the application. If the application contains information that the applicant organization considers to be trade secrets, information that is commercial or financial, or information that is privileged or confidential, the pages containing that information should be identified as specified in the application instructions. When such information is included in the application, it is furnished to the Federal government in confidence, with the understanding that the information will be used or disclosed only for evaluation of the application. The information contained in the application will be protected by DOE from unauthorized disclosure, consistent with the need for merit review of applications of financial assistance awards to assure the integrity of the competitive process and the accuracy and completeness of the information. If a Federal financial assistance award is made as a result of or in connection with an application, the Federal government has the right to use or disclose the information to the extent authorized by law. This restriction does not limit the Federal government's right to use the information if it is obtained without restriction from another source.

Notice to Applicants of Registration Requirements

There are several one-time actions that must be completed before submitting an application in response to this Funding Opportunity Announcement (FOA) (e.g., register with the System for Award Management (SAM), obtain a Unique Entity Identifier (UEI) number, register with Grants.gov, and register with FedConnect.net to submit questions). It is vital that applicants address these items as soon as possible. Some may take several weeks, and failure to complete them could interfere with an applicant's ability to apply to this FOA.

- **SAM**-Each applicant a is required to: (1) register in the SAM at https://www.sam.gov/ before submitting an application; (2) provide a valid UEI number in the application; and (3) maintain an active SAM registration with current information at all times during which it has an active Federal award or an application or plan under consideration by a Federal awarding agency (unless the applicant is exempt from those requirements under 2 CFR 25.110). DOE may not make a Federal award to an applicant until the applicant has complied with all applicable UEI and SAM requirements. If an applicant has not fully complied with the requirements by the time DOE is ready to make a Federal award, DOE will determine that the applicant is not qualified to receive a Federal award and use that determination as a basis for making a Federal award to another applicant.

  Due to the high demand of SAM registrations and UEI requests, entity legal business name and address validations are taking longer than expected to process. Entities should start the SAM and UEI registration process as soon as possible. If entities have technical difficulties with the SAM registration or UEI validation process they should utilize the HELP feature on SAM.gov. SAM.gov will work entity service tickets in the order in which they are received and asks that entities not create multiple service tickets for the same request or technical issue. Additional entity validation resources can be found here: GSAFSD Tier 0 Knowledge Base - Validating your Entity.

- **UEI** Applicants must obtain an UEI from the SAM to uniquely identify the entity. The UEI is available in the SAM entity registration record.

  NOTE: First tier subawardees/subrecipients must also obtain an UEI from the SAM and provide the UEI to the Prime Recipient before the subaward can be issued.

- **Grants.gov** - Applicants must register with Grants.gov at https://www.grants.gov/register to set up your WorkSpace. An applicant cannot submit an application through Grants.gov unless an applicant is registered. Please read the registration requirements carefully and start the process immediately.

  1) The Authorized Organizational Representative (AOR) must register at: https://grants.gov/register.

2) An email is sent to the E-Business (E-Biz) POC listed in SAM.

More information about the registration steps for Grants.gov is provided at: https://apply07.grants.gov/help/html/help/index.htm?callingApp=custom#callingApp=custom&t=Register%2FRegister.html.

In addition:
Add a Profile to a Grants.gov Account: A profile in Grants.gov corresponds to a single applicant organization the user represents (i.e., an applicant) or an individual applicant. If you work for or consult with multiple organizations and have a profile for each, you may log in to one Grants.gov account to access all of your grant applications. To add an organizational profile to your Grants.gov account, enter the UEI for the organization in the UEI field while adding a profile. For more detailed instructions about creating a profile on Grants.gov, refer to: https://apply07.grants.gov/help/html/help/index.htm?callingApp=custom#callingApp=custom&t=Register%2FAddProfile.htm&rhsearch=Add%20a%20profile

- *EBiz POC Authorized Profile Roles*: After you register with Grants.gov and create an Organization Applicant Profile, the organization applicant's request for Grants.gov roles and access is sent to the EBiz POC. The EBiz POC will then log in to Grants.gov and authorize the appropriate roles, which may include the AOR role, thereby giving you permission to complete and submit applications on behalf of the organization. You will be able to submit your application online any time after you have been assigned the AOR role.

  NOTE: When applications are submitted through Grants.gov, the name of the organization applicant with the AOR role that submitted the application is inserted into the signature line of the application, serving as the electronic signature. The EBiz POC **must** authorize people who are able to make legally binding commitments on behalf of the organization as a user with the AOR role; **this step is often missed and it is crucial for valid and timely submissions.**

Questions relating to the **registration process**, **system requirements, or how an application form works** must be directed to Grants.gov at 1-800-518-4726 or **support@grants.gov**.

- **FedConnect.net** - Applicants must register with FedConnect to submit questions. FedConnect website: https://www.fedconnect.net/.

  See Section IV for Application and Submission Information (including how to create a WorkSpace).

SUMMARY OVERVIEW OF KEY INFORMATION

Issuing Agency	Department of Energy, Office of Fossil Energy and Carbon Management (FECM)
Program Overview	This program will provide funding to Carbon Managment
Objective	The program/FOA objective is to expand DOE FECM's carbon management portfolio through support for R&D projects in the programmatic areas of Carbon Conversion, Carbon Dioxide Removal, Point Source Carbon Capture, and Carbon Storage.
Topic Areas	• **Area of Interest (AOI) 1F:** Reactive Carbon Capture Approaches for Point Source Capture or Atmospheric Capture with Integrated Conversion to Useful Products • **Area of Interest (AOI) 3F:** Engineering-Scale testing of Transformational Carbon Capture Technologies for Natural Gas Power Plants (NGPP) • **Area of Interest (AOI) 3G:** Engineering-Scale Testing of Transformational Carbon Capture Technologies in Portables Systems at Industrial Plants • **Area of Interest (AOI) 3H-a:** Preliminary Front-End Engineering and Design Sutdies (Pre-FEED) for Carbon Capture Systems at Existing (Retrofit) Domestic NGPP • **Area of Interest (AOI) 3H-b:** Preliminary Front-End Engineering Design Studies (Pre-FEED) for Carbon Capture Systems at Hydrogrem Production Facilities Using Coal, Mixed Coal/Biomass, or Natural Gas Feedstock • **Area of Interest (AOI) 4A:** Enhancing CO_2 Transport Infrastructure (ECO_2 Transport) Pre-FEED Studies for Multimodal CO_2 Transfer Facilities
Eligible Applicants	See Section III.B. for definitions of eligible applicants • Individuals • Domestic Entities • Domestic Public Entities • Federally Fundinded Research & Development Centers and National Laboratories • Federal Entities • Foreign Entities • DOE/NNSA FFRDC Participation in Project Teams
Funding	It is anticipated that this FOA will provide Federal funding of $78,400,000 over four years. • **Area of Interest (AOI) 1F – Phase 1:** approximately $8,000,000 Federal Funding; 20% Cost Share • **Area of Interest (AOI) 1F – Phase 2:** approximately $24,000,000 Federal Funding; 20% Cost Share • **Area of Interest (AOI) 3F:** approximately $10,000,000 Federal Share; 20% Cost Share • **Area of Interest (AOI) 3G:** approximately $20,000,000 Federal Share; 20% Cost Share

	• **Area of Interest (AOI) 3H-a:** approximately $5,000,000 Federal Share; 20% Cost Share • **Area of Interest (AOI) 3H-b:** approximately $9,000,000 Federal Share; 20% Cost Share • **Area of Interest (AOI) 4A:** approximately $2,400,000 Federal Share; 20% Cost Share
Deadlines	Submission Deadline for Full Applications is October 14, 2024 at 8:00pm ET

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I. Funding Opportunity Description

A. Authorizing Statutes

The programmatic authorizing statutes are:

- Energy Policy Act of 2005, 42 U.S.C. § 15801., et seq. (Public Law 109-58 Title IX, Subtitle F, Sec. 962) as amended.

Awards made under this announcement will fall under the purview of 2 Code of Federal Regulations (CFR) Part 200 as amended by 2 CFR Part 910.

B. Background/Description

i. Background and Purpose

The overall goal of Executive Order 14008 (dated January 27, 2021), "Tackling the Climate Crisis at Home and Abroad," is to "… ensure America and the world can meet the urgent demands of the climate crisis, while empowering American workers and businesses to lead a clean energy revolution that achieves a carbon pollution-free power sector by 2035 and puts the United States on an irreversible path to a net-zero economy by 2050."[1] The Department of Energy's Office of Fossil Energy and Carbon Management (DOE-FECM) has been at the forefront of carbon management research, development, and demonstration (RD&D) for decades, working with partners in industry and academia to solve challenges posed by climate change. This suite of carbon management technologies, including capture, removal, conversion, transport and storage, must be developed and deployed in a just and equitable manner to help the nation achieve its climate ambitions, and promote its overall energy, environmental and economic progress. The development of these technologies supports the ambitious goals for a net-zero greenhouse gas economy by 2050, a carbon pollution free power sector by 2035, and a fifty percent reduction from 2005 levels in economy-wide net greenhouse gas pollution by 2030.

DOE-FECM's Point Source Carbon Capture Program is aiming to develop a variety of technologies for capturing carbon dioxide (CO_2) from large point sources such as industrial sources (e.g., petrochemical/chemicals, cement, and steel production facilities) and coal-based and natural gas (NG) based power plant flue gases.

[1] https://www.energy.gov/sites/default/files/2021/02/f83/eo-14008-tackling-climate-crisis-home-abroad.pdf

Regarding carbon dioxide removal (CDR), FECM aims to invest in the advancement of a diverse set of CDR approaches that will aid in gigatonne-scale removal by 2050. FECM's CDR portfolio aligns with DOE's recently launched Carbon Negative Shot, the U.S. Government's first major effort in CDR, which set the target to achieve "durable and scalable CO_2 removal under $100/net metric ton CO_2e within a decade".[2] FECM emphasizes robust analysis of life cycle impacts of various CDR approaches and a deep commitment to environmental justice. This will include rigorously evaluating CDR practices and technologies, defining conditions for success, and leveraging FECM's extensive leadership and expertise.

The CDR program is aiming to advance DAC technologies through further discovery and optimization of new and novel materials that promote rapid CO_2 uptake, with high dynamic CO_2 capacity under DAC conditions. However, these next-generation, high-performance DAC materials cannot be adequately evaluated until they are integrated with one or more other CO_2 separation equipment components. In this way, the functional material's unique characteristics can be fully leveraged to maximize volumetric CO_2 capture productivity, while reducing pressure drop, maximizing CO_2 contact area, and minimizing heat and power requirements, which will collectively reduce capital and operating costs.

In parallel, DOE-FECM's Carbon Conversion Program is developing technologies for large-scale conversion of CO_2 into environmentally responsible, equitable, and economically valuable products. These include pathways such as mineralization where CO_2 is reacted with an alkaline feedstock to produce building materials such as synthetic aggregates or concrete. Carbonates may be an effective long-term storage option for CO_2, but key technical barriers limiting the economical production of mineralization products using utility or industrial sources of CO_2 must be addressed through applied research and development (R&D). Other conversion pathways include biological uptake of CO_2 through algal systems and catalytical conversion to synthetic fuels and chemicals. In addition, accurate quantification of the economic and environmental benefits of the targeted product via techno-economic analysis and life cycle analysis is a top programmatic priority.

As the need for carbon capture continues to grow, the demand for nearby storage of carbon will continue to increase. DOE-FECM's Carbon Transport &

[2] https://www.energy.gov/sites/default/files/2022-07/Carbon-Negative-Shot-FactSheet_7.5.22%20Updates.pdf

Storage Program seeks to address this need through laboratory, field, pilot, and demonstration-scale projects that validate key concepts and technologies for commercialization. This Program covers transport planning and optimization, repurposing of existing infrastructure, and deep subsurface storage of CO_2. Some of the technologies and information may be adaptable to surface and shallow subsurface *in-situ* and ex-situ storage via mineralization. The Program seeks to support options and geographic opportunities for mineralization-based carbon storage across the U.S. Recognizing the need to meet national decarbonization goals and priorities, DOE is aligning its Programs to catalyze the carbon capture and storage industry for both CO_2 mitigation and removal.

ii. Research and Development Community Benefits Plan (April 2023)

DOE is committed to investing in research and development (R&D) innovations that deliver benefits to the American public and leads to commercialization of technologies and products that foster sustainable, resilient, and equitable access to clean energy. Further, DOE is committed to supporting the development of more diverse, equitable, inclusive, and accessible workplaces to help maintain the nation's leadership in science and technology.

To support the goal of building a clean and equitable energy economy, projects funded under this Funding Opportunity Announcement are expected to (1) advance diversity, equity, inclusion, and accessibility (DEIA); (2) contribute to energy equality; and (3) invest in America's workforce. To ensure these objectives are met, applications must include a R&D Community Benefits Plan (R&D Community Benefits Plan) that addresses the three objectives stated above. See Section IV, "Application and Submission Information, R&D Community Benefits Plan" and the "R&D Community Benefits Plan" Appendix for more information on the R&D Community Benefits Plan content requirements.

iii. Teaming Partner List

DOE is compiling a "Teaming Partner List" to facilitate the formation of new project teams for this FOA. The Teaming Partner List allows organizations who may wish to participate on an application to express their interest to other Applicants and to explore potential partnerships. Participation by partners underrepresented in the industry and diverse suppliers, and by labor unions, is highly encouraged.

Updates to the Teaming Partner List will be available in the FedConnect website in the message center for this opportunity. The Teaming Partner List will be regularly updated to reflect new teaming partners who provide their organization's information. Interested parties must register with FedConnect as an interested party to this FOA in order to have access to the FOA's message center.

SUBMISSION INSTRUCTIONS: Any organization that would like to be included on this list should submit the following information: Organization Name, Contact Name, Contact Address, Contact Email, Contact Phone, Organization Type, Area of Technical Expertise, Brief Description of Capabilities, and Area of Interest. Interested parties shall use the Excel file titled "DOE-FOA-0002614 Teaming Partner List", provided as an Attachment to this announcement. Submit the completed Excel sheet to FOA2614RD6@netl.doe.gov with the subject line "Teaming Partner Information."

DISCLAIMER: By submitting a request to be included on the Teaming Partner List, the requesting organization consents to the publication of the above-referenced information. By facilitating the Teaming Partner List, DOE is not endorsing, sponsoring, or otherwise evaluating the qualifications of the individuals and organizations that are self-identifying themselves for placement on this Teaming Partner List. DOE will not pay for the provision of any information, nor will it compensate any Applicants or requesting organizations for the development of such information.

C. Objectives/Areas of Interest

The current funding opportunity announcement (FOA) aims to expand DOE FECM's carbon management portfolio through support for R&D projects in the programmatic areas of Carbon Conversion, Carbon Dioxide Removal, Point Source Carbon Capture, and Carbon Storage. The various areas of interest and a brief description of each is presented below.

AOI 1. Carbon Conversion Technology

The objective of **AOI-1** is to support R&D investigating the conversion of carbon dioxide (CO_2) into environmentally responsible and economically feasible products. The Carbon Conversion Program will support R&D of technologies that utilize anthropogenic CO_2 from point sources such as power/industrial flue gas and direct air capture to yield valued-added products while simultaneously reducing CO_2 emissions. Supported R&D will validate results through rigorous product testing, life cycle analysis, and techno-economic analysis.

Under the current FOA opening, applications are solicited in the following subtopic:

AOI-1F. Reactive Carbon Capture Approaches for Point Source Capture or Atmospheric Capture with Integrated Conversion to Useful Products

The objective of **AOI-1F** is to (i) perform conceptual design studies for reactive carbon capture (RCC) approaches applied to the atmosphere (i.e., direct air capture, enhanced mineralization, biomass carbon removal, marine CDR) or point source (electric generation or industrial) emissions, and (ii) experimentally validate the RCC approaches at bench scale, showing progress towards a 30% reduction in the product cost and 30% improvement in energy efficiency of carbon capture and conversion via RCC versus a reference conventional process with sequential capture and conversion. A more detailed description of AOI-1F can be found in Appendix A.

AOI-3. Point Source Carbon Capture Technology

The objective of **AOI-3** is to solicit applications that are specifically focused on developing lower cost, highly-efficient technologies for capture of CO_2 from fossil fuel power plants and industrial point sources. The captured CO_2 must be suitable for secure geologic carbon storage, including in situ mineralization or CO_2 conversion into long-lasting products (e.g., synthetic aggregates, concrete, durable carbon products).

Under the current FOA opening, applications are solicited for four subtopics that are introduced below and described more fully in Appendix C.

AOI-3F. Engineering-Scale Testing of Transformational Carbon Capture Technologies for Natural Gas Power Plants (NGPP)

The objective of **AOI-3F** is to (i) test transformational carbon capture technologies at engineering scale under real Natural Gas Power Plant (NGPP) flue gas conditions achieving 95% or greater carbon capture efficiency and 95% CO_2 purity and, (ii) demonstrate significant progress towards a 30% reduction in cost of capture versus a reference NGPP with carbon capture for the reference carbon capture efficiency (i.e., 95%).[3] NGPPs are defined as natural gas combined cycle (NGCC), NGCC with combined heat and power (NGCC-CHP) and natural gas simple cycle (NGSC).

[3] T. Schmitt, S. Leptinsky, M. Turner, A. Zoelle, M. Woods, T. Shultz, and R. James “Fossil Energy Baseline Revision 4a," National Energy Technology Laboratory, Pittsburgh, October 14, 2022.

AOI-3G. Engineering-Scale Testing of Transformational Carbon Capture Technologies in Portable Systems at Industrial Plants

The objective of **AOI-3G** is to (i) test transformational carbon capture technologies at engineering scale under real industrial process/flue gas conditions achieving 95% or greater carbon capture efficiency and 95% CO_2 purity and, (ii) demonstrate the economic viability of the proposed technology in terms of cost of capture and reduction in the increase in the cost of the industrial product that can justify its scale-up in a subsequent program. The industrial sectors of interest for AOI-3G include but are not limited to: (i) chemical production (e.g., petrochemicals) excluding ethanol and ammonia production, (ii) mineral production (e.g., cement and lime), (iii) pulp and paper production, (iv) iron and steel production, (v) glass production, and (vi) oil refining (e.g., catalytic cracker, hydrocracking). Engineering-scale portable systems proposed for AOI-3G must be designed such that they can be moved to other host site locations for additional testing on alternative flue gas sources.

AOI-3H-a. Preliminary Front-End Engineering Design Studies (Pre-FEED) for Carbon Capture Systems at Existing (Retrofit) Domestic NGPP

The objective of **AOI-3H-a** is to execute and complete preliminary front-end engineering design studies of commercial-scale, advanced carbon capture systems that separate CO_2 with at least 95% capture efficiency at existing NGPP. NGPPs are defined as natural gas combined cycle (NGCC), NGCC with combined heat and power (NGCC-CHP) and natural gas simple cycle (NGSC).

AOI-3H-b. Preliminary Front-End Engineering Design Studies (Pre-FEED) for Carbon Capture Systems at Hydrogen Production Facilities Using Coal, Mixed Coal/Biomass, or Natural Gas Feedstock

The objective of **AOI-3H-b** is to execute and complete preliminary front-end engineering design studies of commercial-scale, advanced carbon capture systems that separate CO_2 with at least 95% capture efficiency at new or existing hydrogen production facilities using coal, mixed coal/biomass/municipal solid waste/unrecyclable plastics, or natural gas (including renewable NG) feedstocks.

AOI-4. Carbon Transport and Storage

The Carbon Transport and Storage Program is designed to establish the foundation for a successful carbon storage and transport industry by making key investments in RD&D, large-scale transport and storage facilities and regional hubs to support rapid deployment of carbon capture and storage technologies. The objective of **AOI-4** is to support R&D that investigates the technical challenges facing widescale deployment of both CO_2 transportation infrastructure and geologic CO_2 storage. Projects

awarded under **AOI-4A** will support advancements in infrastructure engineering and design needed for large-scale transport, utilization, and storage.
Under the current FOA opening, applications are solicited in the following subtopic:

AOI-4A. Enhancing CO_2 Transport Infrastructure (ECO_2Transport): Pre-FEED Studies for Multimodal CO_2 Transfer Facilities

Note, AOI-4A was formerly titled "CO_2 National Network for Enhancing Carbon Transport Infrastructure ONshore/Offshore (CO_2NNECTION) Intermodal Transport Hubs". There are no major scope changes to this AOI.

The objective of **AOI-4A** is to support the development of viable and adaptable multimodal transportation infrastructure capable of transferring anthropogenic CO_2 across regional and national CO_2 transportation networks. Applicants are sought to propose to develop preliminary FEED (Pre-FEED) studies for a real-world scenario, commercial-scale multimodal CO_2 transfer facility (referred to as multimodal transfer facility herein). Pre-FEED studies awarded under AOI-4A will consider how the multimodal transfer facilities will be strategically located, designed, and deployed to connect multimodal CO_2 infrastructure in a manner that serves the efficient, equitable, and environmentally responsible expansion of CCS and CDR operations. This will include the evaluation and analysis of technical needs required to interface and connect CO_2 sources and sinks, as well as temporarily store CO_2 within the multimodal transfer facility. A more detailed description of AOI-4A can be found in Appendix D.

Detailed information on each AOI/subtopic being solicited under this FOA opening is contained in Appendices attached to the FOA as follows:

Appendix A – AOI 1 Carbon Conversion Technology
Appendix C – AOI 3 Point Source Carbon Capture Technology
Appendix D – AOI 4 Carbon Transport and Storage

D. Applications Specifically Not of Interest

The following types of applications will be deemed nonresponsive and will not be reviewed or considered (See Section III, Eligibility Information; Responsiveness Criteria):

- Submissions that fall outside the technical parameters specified in Section I, "Funding Opportunity Description; Objectives/Areas of Interest" of the FOA, including but not limited to:

AOI	Not of Interest
1F	• R&D on RCC approaches producing methanol utilizing CO_2 sourced from Direct Air Capture; • R&D on sequential CO_2 capture and conversion approaches, where the processes of capture and conversion are separate; • R&D on CO_2 storage technologies; • R&D on CO_2 compression technologies; • R&D on carbon capture and conversion materials, components or processes not integrated in the reactive capture process; • R&D on technologies producing hydrogen not integrated in the reactive capture process; • Phase 1 applications that include more than 20% experimental effort; • R&D on nitrogen and/or oxygen selective capture/separation materials; • R&D on mineral extraction and processing; and • R&D on sustainably-sourced biomass production, including plant breeding and genetic modification to enhance carbon uptake.
3F	• Laboratory development or screening of any specific material composition, materials system, or individual component design • Carbon capture systems that capture CO_2 from Industrial sources • R&D on CO_2 utilization/conversion technologies • Submissions that either do not propose a host site or propose a host site that is not located in the United States • R&D on biological carbon capture technologies (e.g., algae-based processes) • R&D on carbon dioxide removal technologies (e.g., direct air capture or biomass with carbon capture (BECCS) technologies, enhanced weathering) • R&D on CO_2 compression technologies (other than engineering analysis) • R&D on CO_2 storage technologies (other than engineering analysis)
3G	• Submissions that do not include development of an engineering-scale *portable* system of the proposed carbon capture system; • Submissions that include laboratory development or screening of any specific material composition, materials system, or individual component design • R&D on carbon capture systems at ethanol production and ammonia production facilities • R&D on carbon capture systems at electric generation facilities;

	• Submissions that either do not propose a host site or propose a host site that is not located in the United States • R&D on biological carbon capture technologies (e.g., algae-based processes) • R&D on direct air capture technologies • R&D on CO_2 compression technologies (other than engineering analysis) • R&D on CO_2 storage technologies (other than engineering analysis)
3H-a	• R&D to advance the maturation of post-combustion and pre-combustion carbon capture technologies, other than the required design of a carbon capture system • R&D to advance the maturation of CO_2 conversion technologies • R&D on Direct Air Capture (DAC) approaches • R&D on CO_2 storage technologies, apart from engineering analysis to support the required design of a carbon capture system • R&D on advanced power cycles (e.g., supercritical CO_2 cycle, oxy-combustion and chemical looping configurations) • R&D on technologies to increase CO_2 concentration in the flue gas (e.g., exhaust gas recirculation), other than engineering analysis • R&D on CO_2 compression technologies, other than engineering analysis to support the required design of a carbon capture system • Algae-based carbon capture technologies • Materials screening (computational or experimental) of novel sorbents, solvents, membrane or electrochemical materials • R&D to advance the maturation of carbon dioxide removal technologies such as direct air capture or biomass with carbon capture (BECCS) technologies or enhanced weathering • Submissions that propose a host site that is not located in the United States.
3H-b	• R&D to advance the maturation of post-combustion and pre-combustion carbon capture technologies, other than the required design of a carbon capture system • R&D to advance the maturation of CO_2 utilization/conversion technologies • R&D on CO_2 storage technologies, other than engineering analysis to support the required design of a carbon capture system • R&D on advanced power cycles (e.g., supercritical CO_2 cycle, oxy-combustion and chemical looping configurations) other than engineering analysis • R&D on CO_2 compression technologies, other than engineering analysis to support the required design of a carbon capture system; • Algae-based carbon capture technologies;

	• Materials screening (computational or experimental) of novel sorbents, solvents, membrane or electrochemical materials; • R&D to advance the maturation of carbon dioxide removal technologies (e.g., direct air capture or biomass with carbon capture (BECCS) technologies, enhanced weathering); • Preliminary Front-End Engineering Design Studies for carbon capture systems at Steam Methane Reforming (SMR) hydrogen production facilities • Submissions that propose a host site that is not located in the United States.
4A	• R&D on carbon capture including point source and DAC hubs at the laboratory/bench scale, engineering, or pilot scale; • R&D on CO_2 storage technologies at the laboratory/bench scale, engineering, or pilot scale; • R&D on CO_2 utilization/conversion technologies at the laboratory/bench scale, engineering, or pilot scale; • R&D on CO_2 transportation supportive technologies including compression, liquification, dehydration, and purification that are not in support of a multimodal transfer facility; • R&D on single-mode transportation modalities that are not in support of a multimodal transfer facility; • Submissions that are single CO_2 source and single CO_2 conversion/geologic storage location proposals; • R&D that includes non-anthropogenic CO_2 sources; • R&D that does not adhere to or provide a plan for obtaining legally-approved exceptions, variances or changes to relevant local, state, and/or federal regulations; • Submissions that request funding in excess of the maximum DOE share as outlined in Section II Award Information; • R&D for proposed technologies that are not based on sound scientific principles (e.g., violates the laws of thermodynamics); • Submissions that include scope and/or costs to advance the maturation of CO_2 transport technologies outside of the scope of the pre-FEED study multimodal transfer facility (e.g., designing and constructing new electric generation and industrial facilities); • Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation; and • Submissions including more than one (1) transfer facility.

II. Award Information

A. Type of Application

DOE will accept only new applications under this announcement.

B. Type of Award Instrument

Cooperative Agreements
DOE anticipates awarding cooperative agreements under this funding opportunity announcement (See Section VI, "Award Administration Information; Statement of Substantial Involvement").

C. Award Overview

i. Estimated Funding, Number of Awards, Anticipated Award Size, and Maximum DOE Share

DOE expects to make Federal funding available for new awards under this FOA as follows:

Areas of Interest with Cost Share

Area of Interest	Estimated Federal Funding	Anticipated No. of Awards	Anticipated Individual Award Size			Maximum DOE Share of Award*
			DOE Share* $ / 80%	Cost Share** $ /20%	Total $	
1F -Phase 1	$8,000,000	Up to 20	$400,000	$100,000	$500,000	$400,000
1F -Phase 2	$24,000,000	Up to 08	$3,000,000	$750,000	$3,750,000	$3,000,000
3F	$10,000,000	Up to 02	$5,000,000	$1,250,000	$6,250,000	$5,000,000
3G	$20,000,000	Up to 04	$5,000,000	$1,250,000	$6,250,000	$5,000,000
3H-a	$5,000,000	Up to 02	$2,500,000	$625,000	$3,125,000	$2,500,000
3H-b	$9,000,000	Up to 03	$3,000,000	$750,000	$3,750,000	$3,000,000
4A	$2,400,000	Up to 05	$800,000	$200,000	$1,000,000	$800,000
Totals	**$78,400,000**	**Up to 36**				

*The DOE share listed under the anticipated individual award size is the maximum amount of DOE funding that can be proposed for each Area of Interest. Applications that propose a DOE share in excess of these limits will not be evaluated.

**Applicants may propose cost share in excess of 20% which could result in higher total award values than those stated above.

DOE may issue awards in one, multiple or none of the areas of interests.

APPLICATIONS WHICH EXCEED THE "MAXIMUM DOE SHARE OF AWARD" SPECIFIED ABOVE WILL BE CONSIDERED NONCOMPLIANT (SEE SECTION III,

"ELIGIBILITY INFORMATION; COMPLIANCE CRITERIA"). DOE WILL NOT REVIEW OR CONSIDER NONCOMPLIANT APPLICATIONS.

DOE may establish more than one budget period for each award and fund only the initial budget period(s). Funding for all budget periods, including the initial budget period, is not guaranteed. Funding for all awards and future budget periods are contingent upon the availability of funds appropriated by Congress for the purpose of this program and the availability of future-year budget authority.

Project continuation will be contingent upon satisfactory performance and go/no-go decision review. At the go/no-go decision points, DOE will evaluate project performance, project schedule adherence, meeting milestone objectives, compliance with reporting requirements, and overall contribution to the program goals and objectives. As a result of this evaluation, DOE will make a determination to continue the project, re-direct the project, or discontinue funding the project.

ii. Estimated Project Period of Performance per Area of Interest

The anticipated project period of performance for projects under each Area of Interest in this announcement is:

Area of Interest	Project Period of Performance	Number of Budget Periods
1F - Phase 1	12 months	1
1F - Phase 2	Up to 30 months	2
3F	Up to 48 months	4
3G	Up to 48 months	4
3H-a	Up to 18 months	1
3H-b	Up to 24 months	2
4A	Up to 12 months	1

Typically, budget periods are established on an annual basis. In some cases, shorter or longer budget periods may be established for compelling programmatic or administrative reasons, such as to allow for project phases not evenly divisible with 12-month increments or to provide program personnel with logical decision points to evaluate whether the project should proceed.

III. Eligibility Information

A. General

To be considered for substantive evaluation, an applicant's submission must meet the criteria set forth below. If the application does not meet these initial requirements, it will be considered non-responsive, removed from further evaluation, and ineligible for any award.

B. Eligible Applicants

i. Individuals

U.S. citizens and lawful permanent residents are eligible to apply for funding as a Prime Recipient or Subrecipient.

ii. Domestic Entities

For-profit entities, educational institutions, and nonprofits that are organized, chartered or incorporated (or otherwise formed) under the laws of a particular State or territory of the United States and have a physical location for business operations in the United States are eligible to apply for funding as a Prime Recipient or Subrecipient.

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**.

iii. Domestic Public Entities (excluding Federal entities)

State, local, and tribal government entities are eligible to apply for funding as a Prime Recipient or Subrecipient.

Entities banned from doing business with the United States government such as entities debarred, suspended, or otherwise excluded from or ineligible for participating in Federal programs are not eligible.

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

Federal entity eligibility is discussed below.

iv. Federally Funded Research and Development Centers and National Laboratories

DOE/National Nuclear Security Administration (NNSA) Federally Funded Research and Development Centers (FFRDCs) and National Laboratories (NL) are eligible to apply for funding as a Subrecipient (only) but are not eligible to apply as a Prime Recipient. Non-DOE/NNSA FFRDCs and National Laboratories are eligible to apply for funding as a Subrecipient but are not eligible to apply as a Prime Recipient.

NETL is not eligible for award under this announcement and may not be proposed as a subrecipient on another entity's application. An application that includes NETL as a prime recipient or subrecipient will be considered non-responsive.

Authorization. The cognizant contracting officer for the DOE/NNSA FFRDC/NL or the non-DOE/NNSA Federal agency sponsoring the FFRDC/NL contractor must authorize in writing the use of the FFRDC/NL on the proposed project and this authorization must be submitted with the application. The use of a FFRDC/NL must be consistent with its authority under its award and will not place the laboratory in direct competition with the domestic private sector.

The following wording is acceptable for this authorization:

> "Authorization is granted for the [Name] Laboratory to participate in the proposed project. The work proposed for the laboratory is consistent with or complimentary to the missions of the laboratory, will not adversely impact execution of the [DOE/NNSA/or FEDERAL AGENCY] assigned programs at the laboratory, and will not place the laboratory in direct competition with the domestic private sector."

DOE will NOT fund DOE/NNSA FFRDCs participating as a subrecipient through the DOE field work authorization process. DOE will NOT fund non-DOE/NNSA FFRDCs through an interagency agreement with the sponsoring agency. Therefore, the prime recipient and FFRDC are responsible for entering into an appropriate subaward that will govern, among other things, the funding of the FFRDC portion of the work from the prime recipient under its DOE award. Such an agreement must be entered into before any project work begins.

The applicant should prepare the budgets using rates appropriate for funding the FFRDCs through subawards. The applicant's cost share requirement will be based on the total cost of the project, including the applicant's, the subrecipient's, and the FFRDC's portions of the project.

FFRDC/NL Effort as a Sub-Recipient

The scope of work to be performed by the FFRDC/NL may not be more significant than the scope of work to be performed by the Applicant.

Responsibility. The applicant, if successful, will be the responsible authority regarding the settlement and satisfaction of all contractual and administrative issues, including but not limited to, disputes and claims arising out of any agreement between the applicant and the FFRDC/NL.

v. Federal Entities

Federal agencies and instrumentalities (other than DOE) are eligible to apply for funding as a Subrecipient but are not eligible to apply as a Prime Recipient.

vi. Foreign Entities

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as a Prime Recipient or Subrecipient under this FOA. Other than as provided in the "Individuals" or "Domestic Entities" sections above, all Prime Recipients receiving funding under this FOA must be incorporated (or otherwise formed) under the laws of a State or territory of the United States. If a foreign entity applies for funding as a Prime Recipient, it must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed) under the laws of a State or territory of the United States to be the Prime Recipient. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate.

Foreign entities may request a waiver of the requirement to designate a subsidiary in the United States as the Prime Recipient in the Full Application (i.e., a foreign entity may request that it remains the Prime Recipient on an award). To do so, the Applicant must submit an explicit written waiver request in the Full Application. The "Waiver Requests: Foreign Entity Participation as the Prime Recipient and Performance of Work in the United States" Appendix lists the necessary information that must be included in a request to waive this requirement. The applicant does not have the right to appeal DOE's decision concerning a waiver request.

In the waiver request, the applicant must demonstrate to the satisfaction of DOE that it would further the purposes of this FOA and is otherwise in the economic interests of the United States to have a foreign entity serve as the Prime Recipient. DOE may require additional information before considering the waiver request.

vii. DOE/NNSA FFRDC Participation in Project Teams

DOE/NNSA FFRDC project team members funded directly by DOE must work with their fellow project team members under a cooperative research and development agreement (CRADA), unless otherwise approved by the Contracting Officer, to ensure accountability for project work and appropriate management of intellectual property (IP), e.g., data protection and background IP.

C. Cost Sharing

i. Cost Share Requirements

The cost share must be at least 20% of the total allowable costs for research and development projects (i.e., the sum of the Government share, including FFRDC/NL costs if applicable, and the recipient share of allowable costs equals the total allowable cost of the project) and must come from non-Federal sources unless otherwise allowed by law. See 2 CFR part 200.306 as amended by 2 CFR part 910.130 for the applicable cost sharing requirements.

To assist applicants in calculating proper cost share amounts, DOE has included a cost share information sheet and sample cost share calculation in the "Cost Share Information" Appendix of this FOA.

ii. Legal Responsibility

Applicants will be bound by the cost share proposed in their applications and incorporated into their award.

The cost share requirement applies to the project as a whole, including work performed by members of the project team other than the Prime Recipient. The Prime Recipient is legally responsible for paying the entire cost share. The Prime Recipient's cost share obligation is expressed in the Assistance 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 project period, 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 obligation assumed by Project Team members in subawards or related agreements.

iii. Cost Share Allocation

Each Project Team is free to determine how best to allocate the cost share requirement among the team members. 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.

iv. Cost Share Types and Allowability

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV, "Application and Submission Information; Funding Restrictions". In addition, cost share must be verifiable upon submission of the Full Application. Cost share may be provided in the form of cash or cash equivalents, or in-kind contributions. Cost share must come from non-federal sources (unless otherwise allowed by law), such as project participants, state or local governments, or other third-party financing. DOE Loan Guarantee, cannot be leveraged by applicants to provide the required cost share or otherwise support the same scope that is proposed under a project.

Cost share may be provided by the prime recipient, subrecipients, or third parties (entities that do not have a role in performing the scope of work). Vendors/contractors may not provide cost share. Any partial donation of goods or services is considered a discount and is not allowable.

Cash contributions include, but are not limited to: personnel costs, fringe costs, supply and equipment costs, indirect costs and other direct costs.

In-kind contributions are those where a value of the contribution can be readily determined, verified and justified but where no actual cash is transacted in securing the good or service comprising the contribution. Allowable in-kind contributions include but are not limited to: the donation of volunteer time or the donation of space or use of equipment.

Project teams may use funding or property received from state or local governments to meet the cost share requirement, so long as Federal Government did not provide the funding to the state or local government.

The Recipient may not use the following sources to meet its cost share obligations including, but not limited to:

- Revenues or royalties from the prospective operation of an activity beyond the project period;

- Proceeds from the prospective sale of an asset of an activity;
- Federal funding or property (e.g., Federal grants, equipment owned by the Federal Government); or
- Expenditures that were reimbursed under a separate Federal Program.

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. As all sources of cost share are considered part of total project cost, the cost share dollars will be scrutinized under the same Federal regulations as Federal dollars to 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 are encouraged to refer to 2 CFR 200.306 as amended by 2 CFR 910.130 for additional cost sharing requirements.

Please refer to the "Cost Share Information" Appendix of the FOA.

v. Cost Share Verification

Applicants are required to provide written assurance of their proposed cost share contributions in their Full Applications.

Upon selection for award negotiations, applicants are required to provide additional information and documentation regarding their cost share contributions. Please refer to the "Cost Share Information" Appendix of the FOA.

vi. Cost Share Contributions by FFRDCs

Because FFRDCs and NLs are funded by the Federal Government, costs incurred by FFRDCs and NLs generally may not be used to meet the cost share requirement. FFRDCs and NLs may contribute cost share only if the contributions are paid directly from the contractor's Management Fee or another non-Federal source. In such instance, the FFRDC and NLs must certify in writing that the cost share comes from non-Federal sources.

D. Compliance Criteria

A review of all submitted documents and information is performed to determine if the submissions are in compliance with the FOA requirements. **All submitted information and documents must meet all Compliance Criteria listed below to be eligible for review or the submission will be considered noncompliant. DOE will NOT review or consider noncompliant submissions**.

Full Applications*:* Full Applications are deemed compliant if:

- The Full Application complies with the maximum DOE share of the individual award size in Section II, "Award Information; Award Overview" of the FOA;

- The Full Application complies with the content and form requirements in Section IV, "Application and Submission Information; Form and Content Requirements," and Section IV, "Application and Submission Information; Full Applications "of the FOA; and

- The applicant successfully uploaded all required documents and clicked the "Submit" button in Grants.gov by the deadline stated in the FOA. DOE will not extend the submission deadline for applicants that fail to submit required information by the applicable deadline due to server/connection congestion.

E. Responsiveness Criteria

A review of all submitted documents and information is performed to determine if the submissions are responsive to the FOA requirements. **All submitted information and documents must meet all of the Responsiveness Criteria listed below to be eligible for review or the submission will be considered non-responsive. DOE will NOT review or consider non-responsive submissions.**

Full Applications. Full Applications are deemed responsive if:

- The application meets the technical requirements as described in the "Objectives/Areas of Interest" contained in Section I, "Funding Opportunity Description" of the FOA; and

- The Applicant/application meets the Eligibility Criteria in Section III, "Eligibility Information" of the FOA.

Only compliant/responsive applications will be eligible for a comprehensive merit review.

F. Number of Submittals Eligible for Review

Applicants may submit multiple applications under each area of interest of this FOA; **HOWEVER**, applicants may not submit duplicate applications under multiple areas of interest. Put simply, each submitted application should be distinct and tailored to the specific area of interest.

G. Questions Regarding Eligibility

DOE will not make eligibility determinations for potential applicants prior to the date on which applications to this FOA must be submitted. The decision whether to submit an application in response to this FOA lies solely with the applicant.

IV. Application and Submission Information

A. Form and Content Requirements

All submissions must conform to the following form and content requirements, including maximum page limits (described below) and must be submitted as specifically stated. **Full Applications which do not meet ALL of the form and content requirements listed below will be considered noncompliant (See Section III, "Eligibility Information; Compliance Criteria"). DOE will not review or consider noncompliant submissions.** DOE will not review or consider submissions submitted through means other than specifically stated in the FOA, submissions submitted after the applicable deadline, and incomplete submissions. DOE will not extend deadlines for applicants who fail to submit required information and documents by the applicable deadline due to server/connection congestion.

Full Applications must conform to ALL of the following requirements in order to be considered compliant:

- Each must be submitted in Adobe PDF format unless stated otherwise.
- Each must be written in English.
- All pages must be formatted to fit on 8.5 x 11 inch paper with margins not less than one inch on every side. Use Times New Roman typeface, a black font color, and a font size of 11 point or larger (except in figures or tables, which may be 10 point font). A symbol font may be used to insert Greek letters or special characters, but the font size requirement still applies. References must be included as footnotes or endnotes in a font size of 10 or larger. Footnotes and endnotes are counted toward the maximum page requirement.
- Each submission must not exceed the specified maximum page limit (described below) when printed using the formatting requirements set forth above and **double** spaced. The maximum page limitation includes the cover

page, references, charts, graphs, data, maps, photographs, other pictorial presentations, and other reference material the applicant may include its submission.

Full Applications which do not conform to ALL of the requirements listed above will be considered noncompliant (See Section III, "Eligibility Information; Compliance Criteria"). DOE will NOT review or consider noncompliant submissions.

Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their Full 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 Full Application. Once the Full Application is submitted, applicants may revise or update that submission until the expiration of the applicable deadline. If changes are made, the applicant must resubmit the Full Application, before the applicable deadline.

DOE urges applicants to carefully review their Full Applications and to allow sufficient time for the submission of required information and documents. All Full Applications that pass the initial eligibility review will undergo comprehensive technical merit review according to the criteria identified in Section V, "Application Review Information; Review Criteria" of the FOA.

B. Full Applications

Applicants must submit a Full Application by the specified due date and time to be considered for funding under this FOA. Applicants must complete the mandatory forms and any applicable optional forms (e.g., SF-LLL- Disclosure of Lobbying Activities) in accordance with the instructions on the forms and the additional instructions below. Files that are attached to the forms must be in Adobe Portable Document Format (PDF) unless otherwise specified in this announcement.

i. Application Package

Application forms and instructions are available at https://www.grants.gov/.

ii. Content and Form of Full Application

DOE will not review or consider ineligible Full Applications (see Section III, "Eligibility Information; Compliance Criteria" of the FOA).

Each Full Application must be limited to a **single** area of interest. Concepts or technologies unrelated to the specific area of interest should not be consolidated into a single Full Application.

Full Applications must conform to the following requirements:

Submission	Components	Format	File Name
Full Application (PDF, unless stated otherwise)	SF-424	Form	N/A
	Project/Performance Site Location(s)	Form	N/A
	Project Narrative (**30**-page limitation, see chart below for further instruction)	PDF	Project.pdf
	Summary for Public Release (1 page limit)	PDF	Summary.pdf
	Project Management Plan (**10**-page limitation, see chart below for further instruction)	PDF	PMP.pdf
	Resume	PDF	Resume.pdf
	SF424a Budget Information – Non-Construction Programs File	Microsoft Excel	SF424A.xls or .xlsx
	Budget Justification – SEE DETAILED INSTRUCTIONS BELOW	Microsoft Excel	RecipientBudget Justification.xls or .xlsx
	Subaward Budget Justification, if applicable – SEE DETAILED INSTRUCTIONS BELOW	Microsoft Excel	Subawardee_name BudgetJustification.xls or xlsx
	Budget for DOE/NNSA FFRDC/NL or non-DOE/NNSA FFRDC/NL, if applicable	PDF	Use up to 10 letters of the FFRDC/NL name plus "Budget" as the file name (e.g., FFRDC/NL_nameBudget.xls or xlsx), and click on "Add Optional Other Attachment" to attach.
	Authorization from cognizant Contracting Officer for DOE/NNSA FFRDC/NL or non-DOE FFRDC/NL, if applicable	PDF	Use up to 10 letters of the FFRDC/NL name plus FFRDC as the file name (e.g. anlFFRDC or lincolnFFRDC.pdf)
	Environmental Questionnaire	PDF	Env.pdf
	Cost Share Commitment Letters, if applicable	PDF	CSCL.pdf
	SF-LLL Disclosure of Lobbying Activities, if applicable	Form	N/A
	Waiver Requests, if applicable	PDF	Waiver.pdf

	Performance of Work in the United States waiver request, if applicable	PDF	PerformanceofWork_Waiver.pdf
	Data Management Plan	PDF	DMP.pdf
	R&D Community Benefits Plan (**5-**page limitation, see below for further instruction)	PDF	CBP.pdf
	Current and Pending Support	PDF	CPS.pdf
	Transparency of Foreign Connections	PDF	BusinessSensitive.pdf
	Potentially Duplicative Funding	PDF	PDFN.pdf
	State Point Data Table (AOI-1 and AOI-3 only) (see below for further instructions)	PDF	SPDT.pdf
	Summary of preliminary Techno-Economic Analysis AOI-1 and AOI-3 Only: Applicants should provide a separate report with a **10**-page limitation, see below for further instructions)	PDF	TEA.pdf
	Summary of preliminary Life Cycle Analysis AOI-1 and AOI-3 Only: Applicants should include the summary in a separate report with a **5**-page limitation, see below for further instructions)	PDF	LCA.pdf
	Preliminary Business Case Analysis (BCA) AOI-3H-a and AOI-3H-b only: Summary only, 5-page limitation, see below for further instructions AOI-4A only: See Appendix D for further instructions	PDF	BCA.pdf
	Summary Slide Deck (3 slides)	MS PowerPoint	Slide.ppt
	For AOI-3 (all subtopics) summary of existing process model. (Applicants should include the summary in a separate report with a **5**-page limitation, see below for further instructions)	PDF	ProcessModel.pdf
	AOI-4A Only: Summary of a completed Multimodal Transfer Facility scoping/conceptual/pre-feasibility study	PDF	MTFSummary.pdf
	For AOI-3 (all subtopics) and AOI-4A: Letter(s) of Commitment from at least the potential host site owner	PDF	CIL.pdf
	AOI-4A Only: Regulatory Plan Analysis (see Appendix D for further instructions)	PDF	RPA.pdf

Note: The maximum file size that can be uploaded to the Grants.gov website is 10MB. Files in excess of 10MB cannot be uploaded, and hence cannot be submitted for review. If a file exceeds 10MB but is still within the maximum

page limit specified in the FOA, it must be broken into parts and denoted to that effect. For example:

Project Part 1
Project Part 2, etc.

DOE will not accept late submissions that resulted from technical difficulties due to uploading files that exceed 10MB.

Detailed guidance on the content and form of each component is listed below.

iii. SF-424: Application for Federal Assistance

Complete the SF 424 form first to populate data in other forms. Complete all required fields in accordance with the instructions on the form. The list of certifications and assurances in Field 21 can be found at https://www.energy.gov/management/financial-assistance-forms-and-information-applicants-and-recipients, under Certifications and Assurances.

iv. Project/Performance Site Location(s)

Indicate the primary site where the work will be performed by the prime recipient or subrecipient(s). If a portion of the project will be performed at any other site(s), identify the site location(s) in the blocks provided.

Note that the Project/Performance Site Congressional District is entered in the format of the 2-digit state code followed by a dash and a 3 digit Congressional district code, for example VA-001. Hover over this field for additional instructions.

Use the Next Site button to expand the form to add additional Project/Performance Site Locations.

v. Other Attachments Form

Submit the following files with your application and attach them to the Other Attachments Form. Click on "Add Mandatory Other Attachment" to attach the Project Narrative. Click on "Add Optional Other Attachment," to attach the other files.

vi. Project Narrative File – Mandatory Other Attachment

The Project Narrative File must be submitted in Adobe PDF format. The project narrative must not exceed **30** pages, including cover page, table of contents, footnotes/endnotes, charts, graphs, maps, photographs, and other pictorial presentations, when printed using standard 8.5" by 11" paper with 1 inch margins (top, bottom, left, and right) **double** spaced. The font must not be smaller than 11 point. The **Identification of Potential Conflicts of Interest or Bias in Selection of Reviewers, and Bibliography sections are NOT included in the project narrative page limitation**. Do not include any Internet addresses (URLs) that provide information necessary to review the application. See Section VIII, "Other Information; Treatment of Application Information" for instructions on how to mark proprietary application information.

Submissions that exceed the maximum page limits indicated above will be considered noncompliant and DOE will not review or consider the submission (See Section III, "Eligibility Information; Compliance Criteria").

Save the information in a single file named "Project.pdf," and click on "Add Mandatory Other Attachment" to attach.

The project narrative (**30** page limitation) must include:

SECTION	MAXIMUM PAGE LIMIT* (if applicable)	DESCRIPTION
Cover Page	Included in the page limitation (1-page maximum)	The cover page should include the project title, the specific FOA area of interest being addressed, the Applicant's name, and the names of all team member organizations. In addition, provide the Applicant's technical and business points of contact along (including the Administrative Officer, if applicable) with e-mail addresses and telephone numbers, names of project manager, Senior/Key personnel and their organizations. The cover page should also include the federal and non-federal share of costs associated with each team member's proposed effort. Applicants should ensure the cost information is consistent with the submitted budget justification(s). A sample Project Narrative Cover Page is included as an attachment to this announcement.
Table of Contents	Included in the page limitation	Applicant to capture, at a minimum, all of the required sections identified in this table.

Project Objectives	Included in the page limitation	This section should provide a clear, concise statement of the specific objectives/aims of the proposed project. Buy America Requirements for Infrastructure Projects: Within the first two (2) pages of the Narrative, include a short statement on whether the project will involve the construction, alteration, and/or repair of infrastructure in the United States. See the "Required Use of American Iron, Steel, Manufactured Products, and Construction Materials – Buy America Requirements for Infrastructure Projects" Appendix for applicable definitions and other information to inform this statement.
Merit Review Criterion Discussion	Included in the page limitation	The section should be formatted to address each of the merit review criterion and sub-criterion listed in Section V, "Application Review Information; Review Criteria". Provide sufficient information so that reviewers will be able to evaluate the application in accordance with these merit review criteria. DOE/NNSA WILL EVALUATE AND CONSIDER ONLY THOSE APPLICATIONS THAT ADDRESS SEPARATELY EACH OF THE MERIT REVIEW CRITERION AND SUB-CRITERION.
Statement of Project Objectives	**Included in the page limitation**	The project narrative must contain a single, detailed Statement of Project Objectives that addresses how the project objectives will be met. The Statement of Project Objectives must contain a clear, concise description of all activities to be completed during project performance. It is therefore required that it shall not contain proprietary or confidential business information. The Statement of Project Objectives is generally less than **10** pages in total for the proposed work. Applicants shall prepare the Statement of Project Objectives in the format provided in the "Statement of Project objectives Template" Appendix of the FOA.
Relevance and Outcomes/Impacts	Included in the page limitation	This section should explain the relevance of the effort to the objectives in the program announcement and the expected outcomes and/or impacts. The justification for the proposed project should include a clear statement of the importance of the project in terms of the utility of the outcomes and the target community of beneficiaries.
Roles of Participants	Included in the page limitation	For multi-organizational or multi-investigator projects, describe the roles and the work to be performed by each participant/investigator, business agreements between the applicant and participants, and how the various efforts will be integrated and managed.

Multiple Principal Investigators	Included in the page limitation	The applicant, whether a single organization or team/partnership/consortium, must indicate if the project will include multiple PIs. This decision is solely the responsibility of the applicant. If multiple PIs will be designated, the application must identify the Contact PI/Project Coordinator and provide a "Coordination and Management Plan" that describes the organization structure of the project as it pertains to the designation of multiple PIs. This plan should, at a minimum, include: - process for making decisions on scientific/technical direction; - publications; - intellectual property issues; - communication plans; - procedures for resolving conflicts; and - PIs' roles and administrative, technical, and scientific responsibilities for the project.
Facilities and Other Resources	Included in the page limitation	Identify the facilities (e.g., office, laboratory, computer, etc.) to be used at each performance site listed and, if appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Describe only those resources that are directly applicable to the proposed work. Provide any information describing the other resources available to the project such as machine and electronics shops.
Equipment	Included in the page limitation	List important items of equipment already available for this project and, if appropriate, note the location and pertinent capabilities of each. If you are proposing to acquire equipment, describe comparable equipment, if any, already at your organization and explain why it cannot be used.
Project Narrative Specific Requirements that are included in the page limitations	**Included in the page limitation**	See Section I.C. and the respective Appendices of the FOA for a full list of specific requirements that applicants will need to include in the narrative section of the application, respective to the area of interest.
Identification of Potential Conflicts of Interest or Bias in Selection of Reviewers	**Not included in the page limitation**	Provide the following information in this section: ▪ Collaborators and Co-editors: List in alphabetical order all persons, including their current organizational affiliation, who are, or who have been, collaborators or co-authors with you on a research project, book or book article, report, abstract, or paper during the 48 months preceding the submission of this application. Also, list any individuals who are currently, or have been, co-editors with you on a special issue of a journal, compendium, or conference proceedings during the 24 months preceding the submission of this application. If there are no collaborators or co-editors to report, state "None." ▪ Graduate and Postdoctoral Advisors and Advisees: List the names and current organizational affiliations of your graduate advisor(s) and principal postdoctoral sponsor(s) during the last

		5 years. Also, list the names and current organizational affiliations of your graduate students and postdoctoral associates.
Bibliography	Not included in the page limitation	If applicable: Provide a bibliography for any references cited in the Project Narrative section. This section must include only bibliographic citations.

*As indicated above, a maximum page limit has been established for the project narrative so when the project narrative sections identified in the table above as included in the page limitation are totaled together (including the cover page, table of contents, footnotes / endnotes, charts, graphs, maps, photographs, and other pictorial presentations) it should not exceed **30** pages. Full Applications which do not conform to ALL of the requirements listed above will be considered noncompliant (See Section III, "Eligibility Information; Compliance Criteria"). DOE will not review or consider noncompliant submissions.

vii. Summary for Public Release File (April 2023)

The project summary/abstract must contain a one-page summary of the proposed activity suitable for dissemination to the public. It should be a self-contained document that identifies the name of the applicant, the project director/principal investigator(s), the project title, the objectives of the project, a description of the project, including methods to be employed, the potential impact of the project (i.e., benefits, outcomes), major participants (for collaborative projects), and the project's commitments and goals described in the Community Benefits Plan. This document must not include any proprietary or sensitive business information as the Department may make it available to the public after selections. The project summary must not exceed one (1) page when printed using standard 8.5" by 11" paper with 1" margins (top, bottom, left and right) **double** spaced with font no smaller than 11 point. Save this information in a file named "Summary.pdf," and click on "Add Optional Other Attachment" to attach.

viii. Project Management Plan

The Project Management Plan (PMP) must not exceed 10 pages including cover page, table of contents, footnotes/endnotes, charts, graphs, maps, photographs, and other pictorial presentations, when printed using standard 8.5" by 11" paper with 1" margins (top, bottom, left and right) **double** spaced with font no smaller than 11 point. Applicants shall prepare the PMP in the format provided in the "Project Management Plan Template" Appendix of the FOA. Save this information in a file named "PMP.pdf," and click on "Add Optional Other Attachment" to attach.

ix. Resume File (April 2023)

Provide a resume for each key person proposed, including subawardees and consultants if they meet the definition of key person. A key person is any individual who contributes in a substantive, measurable way to the execution of the project. The biographical information for each resume must not exceed 3 pages when printed on 8.5" by 11" paper with 1 inch margins (top, bottom, left, and right) **double** spaced with font no smaller than 11 point and should include the following information, if applicable:

- Contact Information;
- Education and Training. Undergraduate, graduate and postdoctoral training, provide institution, major/area, degree and year.
- Research and Professional Experience. Beginning with the current position list, in chronological order, professional/academic positions with a brief description. List all current academic, professional, or institutional appointments, foreign or domestic, at the applicant institution or elsewhere, whether or not remuneration is received, and, whether full-time, part-time, or voluntary;
- Awards and honors;
- Publications. Provide a list of up to 10 publications most closely related to the proposed project. For each publication, identify the names of all authors (in the same sequence in which they appear in the publication), the article title, book or journal title, volume number, page numbers, year of publication, and website address if available electronically. An abbreviated style such as the Physical Review Letters (PRL) convention for citations (list only the first author) may be used for publications with more than 10 authors;
- Patents, copyrights, and software systems developed may be provided in addition to or substituted for publications.
- Synergistic Activities. List no more than 5 professional and scholarly activities related to the effort proposed.
- There should be no lapses in time over the past ten years or since age 18, which ever time period is shorter.

As an alternative to a resume, it is acceptable to use the biographical sketch format approved by the National Science Foundation (NSF). The biographical sketch format may be generated by the Science Experts Network Curriculum Vita (SciENcv), a cooperative venture maintained at https://www.ncbi.nlm.nih.gov/sciencv/, and is also available at https://nsf.gov/bfa/dias/policy/nsfapprovedformats/biosketch.pdf. The use of a format required by another agency is intended to reduce the administrative burden to researchers by promoting the use of common formats.

Save all resumes in a single file named "Resume.pdf" and click on "Add Optional Other Attachment" to attach.

x. SF 424A Budget Information – Non-Construction Programs (SF424) File

You must provide a separate budget for each year of support requested and a cumulative budget for the total project period of performance. Use the SF 424 A Excel, "Budget Information - Non Construction Programs" form on the DOE Financial Assistance Forms Page at https://www.energy.gov/management/financial-assistance-forms-and-information-applicants-and-recipients under DOE budget forms.

You may request funds under any of the Object Class Categories as long as the item and amount are necessary to perform the proposed work, meet all the criteria for allowability under the applicable Federal cost principles, and are not prohibited by the funding restrictions in this announcement (See Section IV, “Application and Submission Information; Funding Restrictions”). Save the information in a single file named "SF424A.xls or xlsx," and click on "Add Optional Other Attachment" to attach.

xi. Budget Justification File

Applicants are required to provide a detailed budget justification for the project as a whole, including all work to be performed by the Applicant and its Subrecipients and Contractors, and provide all requested documentation (e.g., a Federally-approved rate agreement, contractor quotes). Applicants should include costs associated with the Buy America Requirements for Infrastructure projects and Community Benefits Plan, required annual audits and incurred cost proposals in their proposed budget documents. Such costs may be reimbursed as direct or indirect costs.

A Budget Justification workbook is included as an attachment to this announcement for use and to describe the level of detail required in the budget justification. Although the data requested is mandatory, the use of the budget justification workbook is not.

The “Instructions and Summary” included with the Budget Justification workbook will auto-populate as the applicant enters information into the workbook. Applicants must carefully read the “Instructions and Summary” tab provided within the Budget Justification workbook. In addition, Applicants must carefully read and note each “Instructions” Summary contained within each individual tab of the Budget Justification workbook.

As stipulated within the Budget Justification workbook, all direct costs must be identified by specific task. All cost should include the basis of cost and justification of need, as applicable. Of specific note is the necessity to identify personnel costs for each individual proposed for all tasks to which they are assigned. Note EXAMPLES provided within each tab for further clarification.

DOE understands that projects selected under this FOA may require the use of existing data. For purposes of this FOA, DOE will consider data that is commercially available at an established price to be an allowable cost under the project (either as DOE share or non-federal cost share) but DOE will not consider in-kind data (e.g., data, owned by an entity, that is not routinely sold commercially but is instead donated to the project and assigned a value) to be an allowable cost under the project, including as Recipient cost share. Estimation methods used by the Recipient to assign a value to in-kind data cannot be objectively verified by DOE and therefore will not be accepted by DOE as an allowable cost under any project selected from this FOA. Consequently, DOE will not recognize in-kind data costs in any resulting approved DOE budget.

Save the Budget Justification workbook in a single file named "RecipientBudgetJustification.xls or xlsx" and click on "Add Optional Other Attachment" to attach.

xii. Subaward Budget Justification (if applicable)

Applicants must provide a separate detailed budget justification for each subrecipient that is expected to perform work estimated to be more than $250,000 or 25 percent of the total work effort (whichever is less). A Budget Justification workbook is included as an attachment to this announcement. Although the data requested is mandatory, the use of the budget justification workbook is not. The level of detail to be included in the subaward budget justification (if applicable) must be commensurate with that provided by the Prime Recipient. Save the information in a single file named "Subawardee_name BudgetJustification.xls or xlsx" and click on "Add Optional Other Attachment" to attach.

xiii. Budget for DOE/NNSA FFRDC/NLs or non-DOE/NNSA FFRDC/NLs, (if applicable)

If proposed, FFRDC/NLs will be treated as subawards for applicants. Therefore, prepare the budgets utilizing rates appropriate for such an arrangement. You must provide a separate detailed budget justification for

each FFRDC/NL proposed that is expected to perform work estimated to be more than $250,000 or 25 percent of the total work effort (whichever is less). A Budget Justification workbook is included as an attachment to this announcement. Although the data requested is mandatory, the use of the budget justification workbook is not. The level of detail to be included in the FFRDC/NL budget justification (if applicable) must be commensurate with that provided by the Prime Recipient. Use up to 10 letters of the FFRDC/NL name plus "Budget" as the file name (e.g., FFRDC/NL_nameBudget.xls or xlsx), and click on "Add Optional Other Attachment" to attach.

If a DOE/NNSA FFRDC/NL is to perform a portion of the work, you shall use the Department's Strategic Partnership Projects program in accordance with the requirements of DOE Order 481.1 Strategic Partnership Projects (SPP) [formerly known as "Work for Others" (WFO)]. This order and the applicable terms and conditions are available at https://www.directives.doe.gov/directives-documents/400-series/0481.1-BOrder-e-chg1-ltdchg. Subawards to other FFRDCs will utilize the terms and conditions of the sponsoring agency.

xiv. Authorization for DOE/NNSA FFRDC/NLs or non-DOE/NNSA FFRDCs/NLs (if applicable)

The cognizant contracting officer for the DOE/NNSA FFRDC/NL or the non-DOE/NNSA Federal agency sponsoring the FFRDC must authorize in writing the use of the FFRDC on the proposed project, and this authorization, as specified in Section III, "Eligibility Information" of the FOA, must be submitted with the application. The use of a FFRDC must be consistent with the contractor's authority under its award. Use up to 10 letters of the FFRDC name plus FFRDC as the file name (e.g., lanlFFRDC.pdf or lincolnFFRDC.pdf), and click on "Add Optional Other Attachment" to attach.

xv. Environmental Questionnaire

The Applicant must submit an environmental questionnaire providing for the work of the entire project. The Applicant is also responsible for submitting a separate environmental questionnaire for each proposed subrecipient performing at a different location. The environmental questionnaire is available at https://netl.doe.gov/sites/default/files/2018-02/451_1-1-3.pdf. Save the questionnaire in a single file named "Env.pdf" (or "Env-FILL IN TEAM MEMBER.pdf" if more than questionnaire is submitted) and click on "Add Optional Other Attachment" to attach.

NOTE: If selected for award and if a subrecipient's location is not known at the time of application, a subsequent environmental questionnaire will be needed prior to them beginning work at an alternate location.

xvi. Cost Share Commitment Letters (if applicable)

Cost share commitment letters are required from any party (other than the organization submitting the application) proposing to provide all or part of the required cost share (including subrecipients). The letter should state the party is committed to providing a specific minimum dollar amount of cost share, identify the type of proposed cost share (e.g., cash, services, and/or property) to be contributed, and be signed by the person authorized to commit the expenditure of funds by the entity. The applicant should submit the letter(s) in PDF format. Save this information in a single file named "CSCL.pdf" and click on "Add Optional Other Attachment" to attach.

xvii. Team Member Commitment Letters (required if proposed as a team member)

Letters should demonstrate the team member's level of commitment to the project, such as data access, and/or advisory services, etc. Letter(s) must be signed by the person authorized to commit resources on behalf of the organization and be provided in PDF format. Save this information in a single file named "TMCL.pdf" and click on "Add Optional Other Attachment" to attach.

Letters of support or endorsement for the project from entities that do not have a substantive role in the project are not accepted.

xviii. SF-LLL: Disclosure of Lobbying Activities (if applicable)

Recipients and Subrecipients may not use any Federal funds to influence or attempt to influence, directly or indirectly, congressional action on any legislative or appropriation matters.

If applicable, complete SF-LLL. Applicability: If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the grant/cooperative agreement, you must complete and submit Standard Form - LLL, "Disclosure of Lobbying Activities."

xix. Waiver Requests (if applicable)

i. Foreign Entity Participation

As set forth in Section III., all recipients must qualify as domestic entities. To request a waiver of this requirement, the applicant must submit an explicit waiver request in the Full Application. Appendix F lists the information that must be included in a waiver request.

ii. Performance of Work in the United States (Foreign Work Waiver)

As set forth in Section IV. J., all work for the projects selected under this FOA must be performed in the United States. To request a waiver of this requirement, the applicant must submit an explicit waiver request in the Full Application. Appendix F lists the information that must be included in a waiver request.

Save the Waivers in a single PDF file using the following naming convention for the title "Waiver.pdf" and click on "Add Optional Other Attachment" to attach.

xx. Data Management Plan

Applicants are required to submit a Data Management Plan as part of their Full Application. The Data Management Plan is a document that outlines the proposed plan for data sharing or preservation. Submission of this plan is required with the full application, and failure to submit the plan may result in rejection of the application without further consideration. Applicants shall prepare the DMP in the format provided in the "Data Management Plan" Appendix of this FOA. Save this plan in a single file named "DMP.pdf" and click on "Add Optional Other Attachment" to attach.

xxi. R&D Community Benefits Plan (April 2023)

The R&D Community Benefits Plan must set forth the applicant's approach to ensuring the Federal investments advance the following three (3) objectives: (1) advance diversity, equity, inclusion and accessibility (DEIA); (2) contribute to energy equity; and (3) invest in America's workforce. The below sections set forth the content requirements for the R&D Community Benefits Plan, which addresses each of the foregoing objectives. Applicants must address all three (3) sections.

The applicant's R&D Community Benefits Plan must include at least one Specific, Measurable, Attainable, Realistic, and Timely (SMART) milestone per budget period to measure progress on the proposed actions. The R&D

Community Benefits Plan will be evaluated as part of the technical review process. If a project is selected and awarded, the R&D Community Benefits Objectives and Outcomes Summary Table will be incorporated into the award and the recipient must implement its R&D Community Benefits Plan as part of carrying out its project. During the life of the award, the DOE will evaluate the recipient's progress.

The plan should be specific to the proposed project and not a restatement of organizational policies. Applicants should describe the future implications or a milestone-based plan for identifying future implications of their research on energy equity, including, but not limited to, benefits for the U.S. workforce. These impacts may be uncertain, occur over a long period of time, and/or have many factors within and outside the specific proposed research. Applicants are encouraged to describe the influencing factors and the most likely workforce and energy equity implications of the proposed research if the research is successful. While some guidance and example activities are provided in the "R&D Community Benefits Plan Guidance" and "R&D Community Benefits Plan Template" Appendices, applicants are encouraged to leverage promising practices and develop a plan that is tailored for their project.

The Applicant's R&D Community Benefits Plan must address the following three (3) sections:

1) Diversity, Equity, Inclusion, and Accessibility (DEIA):
To building a clean and equitable energy economy, it is important that there are opportunities for people of all racial, ethnic, socioeconomic and geographic backgrounds, sexual orientation, gender identify, persons with disabilities, and those re-entering the workforce from incarceration. This section of the plan must demonstrate how DEIA is incorporated in the technical project objectives. The plan must identify the specific action the applicant would undertake that integrated into the research goals and project teams. Submitting an institutional DEIA plan without specific integration into the project will be deemed insufficient.

2) Energy Equity:
This section must articulate the applicant's consideration of long-term equity implications of the research. It must identify how the specific project integrates equity considerations into the project design to support equitable outcomes should the innovation be successful. Like cost reductions and commercialization plans, the R&D Community Benefits Plan requires description of the equity implications of the innovation.

3) Workforce Implications:

This section must articulate the applicant's consideration of long-term workforce impacts and opportunities for the research. It must identify how the project is designed and executed to include an understanding of the future workforce needs should the resulting innovations be successful.

See the "R&D Community Benefits Plan Guidance" and "R&D Community Benefits Plan Template" Appendices for additional guidance.

The R&D Community Benefits Plan must not exceed 5 pages. Save this plan in a single file named 'CBP.pdf' and click on "Add Optional Other Attachment" to attach.

xxii. Current and Pending Support

Current and pending support is intended to allow the identification of potential duplication, overcommitment, potential conflicts of interest or commitment, and all other sources of support. As part of the application, the principal investigator and all Senior/Key Personnel at the applicant and subrecipient level must provide a list of all sponsored activities, awards, and appointments, whether paid or unpaid; provided as a gift with terms or conditions or provided as a gift without terms or conditions; full-time, part-time, or voluntary; faculty, visiting, adjunct, or honorary; cash or in-kind; foreign or domestic; governmental or private-sector; directly supporting the individual's research or indirectly supporting the individual by supporting students, research staff, space, equipment, or other research expenses. All connections with foreign government-sponsored talent recruitment programs must be identified in current and pending support.

For every activity, list the following items:

- The sponsor of the activity or the source of funding;
- The award or other identifying number;
- The title of the award or activity. If the title of the award or activity is not descriptive, add a brief description of the research being performed that would identify any overlaps or synergies with the proposed research;
- The total cost or value of the award or activity, including direct and indirect costs and cost share. For pending proposals, provide the total amount of requested funding;
- The award period (start date through end date); and
- The person-months of effort per year being dedicated to the award or activity.

To identify overlap, duplication of effort, or synergistic efforts, append a description of the other award or activity to the current and pending support.

Details of any obligations, contractual or otherwise, to any program, entity, or organization sponsored by a foreign government must be provided on request to either the applicant institution or DOE. Supporting documents of any identified source of support must be provided to DOE on request, including certified translations of any document.

PIs and Senior/Key Personnel must provide a separate disclosure statement listing the required information above regarding current and pending support. Each individual must sign and date their respective disclosure statement and include the following certification statement:

> *I, [Full Name and Title], certify to the best of my knowledge and belief that the information contained in this Current and Pending Support Disclosure Statement is true, complete and accurate. I understand that any false, fictitious, or fraudulent information, misrepresentations, half-truths, or omissions of any material fact, may subject me to criminal, civil or administrative penalties for fraud, false statements, false claims or otherwise. (18 U.S.C. §§ 1001 and 287, and 31 U.S.C. §§ 3729-3733 and 3801-3812). I further understand and agree that (1) the statements and representations made herein are material to DOE's funding decision, and (2) I have a responsibility to update the disclosures during the project period of performance of the award should circumstances change which impact the responses provided above.*

The information may be provided in the approved common disclosure format available at https://www.nsf.gov/bfa/dias/policy/researchprotection/commonform_cps.pdf.

Regardless of the format used, the individual must still include a signature, date, and a certification statement using the language included in the paragraph above.

Save this plan in a single file named "CPS.pdf" and click on "Add Optional Other Attachment" to attach.

Definitions:

Current and pending support – (a) All resources made available, or expected to be made available, to an individual in support of the individual's RD&D

efforts, regardless of (i) whether the source is foreign or domestic; (ii) whether the resource is made available through the entity applying for an award or directly to the individual; or (iii) whether the resource has monetary value; and (b) includes in-kind contributions requiring a commitment of time and directly supporting the individual's RD&D efforts, such as the provision of office or laboratory space, equipment, supplies, employees, or students. This term has the same meaning as the term Other Support as applied to researchers in NSPM-33: For researchers, Other Support includes all resources made available to a researcher in support of and/or related to all of their professional RD&D efforts, including resources provided directly to the individual or through the organization, and regardless of whether or not they have monetary value (e.g., even if the support received is only in-kind, such as office/laboratory space, equipment, supplies, or employees). This includes resource and/or financial support from all foreign and domestic entities, including but not limited to, gifts provided with terms or conditions, financial support for laboratory personnel, and participation of student and visiting researchers supported by other sources of funding.

Foreign Government-Sponsored Talent Recruitment Program – An effort directly or indirectly organized, managed, or funded by a foreign government, or a foreign government instrumentality or entity, to recruit science and technology professionals or students (regardless of citizenship or national origin, or whether having a full-time or part-time position). Some foreign government-sponsored talent recruitment programs operate with the intent to import or otherwise acquire from abroad, sometimes through illicit means, proprietary technology or software, unpublished data and methods, and intellectual property to further the military modernization goals and/or economic goals of a foreign government. Many, but not all, programs aim to incentivize the targeted individual to relocate physically to the foreign state for the above purpose. Some programs allow for or encourage continued employment at United States research facilities or receipt of federal research funds while concurrently working at and/or receiving compensation from a foreign institution, and some direct participants not to disclose their participation to United States entities. Compensation could take many forms including cash, research funding, complimentary foreign travel, honorific titles, career advancement opportunities, promised future compensation, or other types of remuneration or consideration, including in-kind compensation.

Senior/Key Personnel – An individual who contributes in a substantive, meaningful way to the scientific development or execution of a research,

development and demonstration (RD&D) project proposed to be carried out with DOE award.[4]

xxiii. U.S. Manufacturing Commitments

A primary objective of DOE's multi-billion dollar research, development, and demonstration investments is to cultivate new research and development ecosystems, manufacturing capabilities, and supply chains for and by United States industry and labor. Therefore, in exchange for receiving taxpayer dollars to support an applicant's project, the applicant/recipient and any subrecipient and contractor must agree to a U.S. Competitiveness provision requiring that any products embodying any subject invention or produced through the use of any subject invention will be manufactured substantially in the United States unless the applicant/ recipient can show to the satisfaction of DOE that it is not commercially feasible. Award terms, including the specific U.S. Competitiveness Provision applicable to the various types of recipients and projects, are available at https://www.energy.gov/gc/standard-intellectual-property-ip-provisions-financial-assistance-awards.

Please note that a subject invention is any invention conceived or first actually reduced to practice in performance of work under an award. An invention is any invention or discovery which is or may be patentable. The recipient includes any awardee, recipient, subawardee, or subrecipient.

As noted in the U.S. Competitiveness Provision, if an entity cannot meet the requirements of the U.S. Competitiveness Provision, the entity may request a modification or waiver of the U.S. Competitiveness Provision. For example, the entity may propose modifying the language of the U.S. Competitiveness Provision in order to change the scope of the requirements or to provide more specifics on the application of the requirements for a particular technology. As another example, the entity may request that the U.S. Competitiveness Provision be waived in lieu of a net benefits statement or United States manufacturing plan. The statement or plan would contain specific and enforceable commitments that would be beneficial to the United States economy and competitiveness. Examples of such commitments could include manufacturing specific products in the United States, making a specific investment in a new or existing United States manufacturing facility, keeping certain activities based in the United States or supporting a certain number of jobs in the United States related to the technology. DOE may, in its sole discretion, determine that the proposed modification or waiver promotes commercialization and provides

[4] Typically, these individuals have doctoral or other professional degrees, although individuals at the masters or baccalaureate level may be considered senior/key personnel if their involvement meets this definition. Consultants, graduate students, and those with a postdoctoral role also may be considered senior/key personnel if they meet this definition.

substantial United States economic benefits, and grant the request. If granted, DOE will modify the award terms and conditions for the requesting entity accordingly.

More information and guidance on the waiver and modification request process can be found in the DOE Financial Assistance Letter on this topic, available at https://www.energy.gov/management/pf-2022-09-fal-2022-01-implementation-doe-determination-exceptional-circumstances-under. Additional information on DOE's Commitment to Domestic Manufacturing for DOE-funded R&D is available at https://www.energy.gov/gc/us-manufacturing.

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

xxiv. State Point Data Table

Only required for AOI-1 and AOI-3.

Applicants shall prepare the State Point Data Table for conditions similar to the ones in the proposed performance of the award, in the format provided in the "State Point Data Tables for AOI 1" and "State Point Data Tables for AOI 3" Appendix S and Appendix T respectively.

Applicants shall submit the State Point Data Table as a separate document to the FOA project narrative. Note that the State-Point Data Table is required to be completed and submitted with the application. Save this information in a single file named "SPDT.pdf" and click on "Add Optional Other Attachment" to attach.

xxv. Summary of the Preliminary Techno-Economic Analysis

Only required for AOI-1 and AOI-3.

Applicants are required to submit a separate report of the results of a preliminary techno-economic analysis (TEA). The summary of the preliminary TEA must not exceed 10 pages including cover page, table of contents, footnotes/endnotes, charts, graphs, maps, photographs, and other pictorial presentations, when printed using standard 8.5" by 11" paper with 1" margins (top, bottom, left and right) single spaced with font no smaller than 11 point. The Applicant should submit the summary of the preliminary TEA in

PDF format. Save this information in a single file named “TEA.pdf” and click on “Add Optional Other Attachment” to attach.

See the “Basis for Techno-Economic Analysis” Appendix for additional guidance.

xxvi. Summary of Preliminary Life Cycle Analysis

Only required for AOI-1 and AOI-3.

Applicants are required to submit summary results of a preliminary life cycle analysis (LCA) of the proposed technology.

Applicants are required to submit a separate report of the results of a preliminary LCA. Save this information in a single file named “LCA.pdf” and click on “Add Optional Other Attachment” to attach. The file must not exceed 5 pages.

See the “Life Cycle Analysis Requirements” Appendix for additional guidance.

xxvii. Summary of Preliminary Business Case Analysis (AOI-3H-a, AOI-3H-b, and AOI-4A only)

AOI-3H-a and AOI-3H-b: Applicants are required to submit summary results of a Preliminary Business Case Analysis (BCA). The preliminary BCA included in the application should be prepared based upon prior engineering design and costing work, and does not necessarily have to conform to the requirements in Appendix V of the FOA.

AOI-4A: Applicants are required to submit a Preliminary BCA. The Preliminary BCA included in the application must be submitted in accordance with the requirements and format provided in Appendix D and Appendix X. This preliminary business case analysis must demonstrate an understanding of the current and projected commercial viability of the proposed project.

The file must not exceed 5 pages. Save this information in a single file named “BCA.pdf” and click on “Add Optional Other Attachment” to attach.

xxviii. Summary Slide Deck

Applicants must provide a slide deck (no more than three slides) summarizing the proposed project. The Summary Slide Deck must include the following information:

- Project title, Applicant, Principal Investigator, and senior/key personnel information;
- Requested DOE funds and proposed Applicant cost share;
- A summary of the proposed technology;
- A description of the technology's decarbonization potential;
- Proposed project goals including key technical and cost targets;
- Any key graphics (illustrations, charts and/or tables); and
- Topline R&D community benefits.

Save the Summary Slide Deck in a single Microsoft PowerPoint file using the following convention for the title "Slide.ppt" and click on "Add Optional Other Attachment" to attach.

xxix. U.S. Competitiveness

A primary objective of DOE's multibillion-dollar research, development and demonstration investments is to cultivate new research and development ecosystems, manufacturing capabilities, and supply chains for and by U.S. industry and labor. Therefore, in exchange for receiving taxpayer dollars to support an applicant's project, the applicant must agree to the following U.S. Competitiveness Provision as part of an award under this FOA.

U.S. Competitiveness
The Recipient agrees that any products embodying any subject invention or produced through the use of any subject invention will be manufactured substantially in the United States unless the Recipient can show to the satisfaction of DOE that it is not commercially feasible. In the event DOE agrees to foreign manufacture, there will be a requirement that the Government's support of the technology be recognized in some appropriate manner, e.g., alternative binding commitments to provide an overall net benefit to the U.S. economy. The Recipient agrees that it will not license, assign or otherwise transfer any subject invention to any entity, at any tier, unless that entity agrees to these same requirements. Should the Recipient or other such entity receiving rights in the invention(s): (1) undergo a change in ownership amounting to a controlling interest, or (2) sell, assign, or otherwise transfer title or exclusive rights in the invention(s), then the assignment, license, or other transfer of rights in the subject invention(s) is/are suspended until approved in writing by DOE. The Recipient and any successor assignee will convey to DOE, upon written request from DOE, title to any subject invention, upon a breach of this paragraph. The Recipient will include this paragraph in all subawards/contracts, regardless of tier, for experimental, developmental or research work.

Please note that a subject invention is any invention conceived or first actually reduced to practice in performance of work under an award. An invention is any invention or discovery which is or may be patentable. The recipient shall ensure that these requirements also apply to subrecipients.

As noted in the U.S. Competitiveness Provision, if any entity cannot meet the requirements of the U.S. Competitiveness Provision, the entity may request a modification or waiver of the U.S. Competitiveness Provision. For example, the entity may propose modifying the language of the U.S. Competitiveness Provision in order to change the scope of the requirements or to provide more specifics on the application of the requirements for a particular technology. As another example, the entity may request that the U.S. Competitiveness Provision be waived in lieu of a net benefits statement or U.S. manufacturing plan. The statement or plan would contain specific and enforceable commitments that would be beneficial to the U.S. economy and competitiveness. Examples of such commitments could include manufacturing specific products in the U.S., making a specific investment in a new or existing U.S. manufacturing facility, keeping certain activities based in the U.S. or supporting a certain number of jobs in the U.S. related to the technology. DOE may, in its sole discretion, determine that the proposed modification or waiver promotes commercialization and provides sufficient U.S. economic benefits, and grant the request. If granted, DOE will modify the award terms and conditions for the requesting entity accordingly. If not granted, the requesting entity must continue to perform according to the existing terms and conditions. More information and guidance on the waiver and modification request process can be found in the DOE Financial Assistance Letter on this topic.

The U.S. Competitiveness Provision is implemented by DOE pursuant to a Determination of Exceptional Circumstances (DEC) under the Bayh-Dole Act and DOE Patent Waivers. See Section VIII, “Other Information; Intellectual Property Developed Under This Program” of this FOA for more information on the DEC and DOE Patent Waiver.

xxx. Transparency of Foreign Connections

Applicants must provide the following information as it relates to the proposed recipient and subrecipients. Include a separate disclosure for the applicant and each proposed subrecipient. U.S. National Laboratories, domestic government entities, and institutions of higher education are only required to respond to items 1, 2 and 9, and if applying as to serve as the prime recipient, must provide complete responses for project team members

that are not U.S. National Laboratories, domestic government entities, or institutions of higher education.

1. Entity name, website address, and physical address;
2. The identity of all owners, principal investigators, project managers, and Senior/Key Personnel who are a party to any *Foreign Government-Sponsored Talent Recruitment Program* of a foreign country of risk (i.e., China, Iran, North Korea, and Russia);
3. The existence of any joint venture or subsidiary that is based in, funded by, or has a foreign affiliation with any foreign country of risk, including the People's Republic of China;
4. Any current or pending contractual or financial obligation or other agreement specific to a business arrangement, or joint venture-like arrangement with an enterprise owned by a foreign state or any foreign entity;
5. Percentage, if any, that the proposed recipient or subrecipient has foreign ownership or control;
6. Percentage, if any, that the proposed recipient or subrecipient is wholly or partially owned, directly or indirectly, by an entity in a foreign country of risk;
7. Percentage, if any, of venture capital or institutional investment by an entity that has a general partner or individual holding a leadership role in such entity who has a foreign affiliation with any foreign country of risk;
8. Any technology licensing or intellectual property sales to a foreign country of risk, during the 5-year period preceding submission of the proposal;
9. Any foreign business entity, offshore entity, or entity outside the United States related to the proposed recipient or subrecipient;
10. Any foreign equipment that will be used on the project:
    a. Equipment originally made or manufactured in a foreign country of risk (including relabeled or rebranded equipment).
    b. Coded equipment where the source code is written in a foreign country of risk.
    c. Equipment from a foreign country of risk that will be connected to the internet or other remote communication system.
    d. Any companies from a foreign country of risk that will have physical or remote access to any part of the equipment used on the project after delivery.
11. Complete list of all directors (and board observers), including their full name, citizenship and shareholder affiliation, date of appointment, duration of term, as well as a description of observer rights as applicable;
12. Complete capitalization table for your entity, including all equity interests (including LLC and partnership interests, as well as derivative

securities). Include both the number of shares issued to each equity holder, as well as the percentage of that series and all equity on a fully diluted basis.

13. Identify the principal place of incorporation (or organization) for each equity holder. If the equity holder is a natural person, identify the citizenship(s). If the recipient or subrecipient is a publicly traded company, provide the above information for shareholders with an interest greater than 5%;
14. A summary table identifying all rounds of financing, the purchase dates, the investors for each round, and all the associated governance and information rights obtained by investors during each round of financing; and
15. An organization chart to illustrate the relationship between your entity and the immediate parent, ultimate parent, and any intermediate parent, as well as any subsidiary or affiliates. Identify where each entity is incorporated.

DOE reserves the right to request additional or clarifying information based on the information submitted.

Save the Transparency of Foreign Connections information in a single PDF file named "BusinessSensitive.pdf" and click on "Add Optional Other Attachment" to attach.

xxxi. Potentially Duplicative Funding Notice

If the applicant or project team member has other active awards of federal funds, the applicant must determine whether the activities of those awards potentially overlap with the activities set forth in its application to this FOA. If there is a potential overlap, the applicant must notify DOE in writing of the potential overlap and state how it will ensure any project funds (i.e., recipient cost share and federal funds) will not be used for identical cost items under multiple awards. Likewise, for projects that receive funding under this FOA, if a recipient or project team member receives any other award of federal funds for activities that potentially overlap with the activities funded the DOE award, the recipient must promptly notify DOE in writing of the potential overlap and state whether project funds from any of those other federal awards have been, are being, or are to be used (in whole or in part) for one or more of the identical cost items under the DOE award. If there are identical cost items, the recipient must promptly notify the DOE Contracting Officer in writing of the potential duplication and eliminate any inappropriate duplication of funding.

Save the Potentially Duplicative Funding Notice in a single PDF file using the following naming convention for the title "PDFN.pdf" and click on "Add Optional Other Attachment" to attach.

xxxii. Summary of Process Model(s)

Only required for AOI-3.

For AOI-3 (all subtopics), applicants are expected to provide a summary of the process models developed to-date for the proposed carbon capture technology, including but not limited to: (i) model assumptions, (ii) kinetics, mass-transfer, and heat-transfer correlations and their validation, (iii) model predictions for temperature/concentration profiles for major unit operations (e.g., absorber, desorber) and their validation with experimental data. Applicants shall prepare the summary of the process model in a separate document.

The summary of the existing process model must not exceed 5 pages including cover page, table of contents, footnotes/endnotes, charts, graphs, and other pictorial presentations, when printed using standard 8.5" by 11" paper with 1" margins (top, bottom, left and right) single spaced with font no smaller than 11 point. The Applicant should submit the summary of the existing process model in PDF format. Save this information in a single file named "ProcessModel.pdf" and click on "Add Optional Other Attachment" to attach.

See Appendix U - Process Model Requirements - for additional guidance.

xxxiii. Summary of a Completed Multimodal Transfer Facility Scoping/Conceptual/Pre-feasibility Study (AOI-4A)

Only required for AOI-4A.

Applicants are required to provide a summary of a completed Multimodal Transfer Facility scoping/conceptual/pre-feasibility study in accordance with Appendix D, Section III.A. Save this information in a single file named "MTFSummary.pdf" and click on "Add Optional Other Attachment" to attach.

xxxiv. Letter(s) of Commitment (AOI-3 and AOI-4A)

A commitment letter for the proposed host site (power generation, industrial, or multimodal CO_2 transfer facility) must be provided, as described in Appendix C for AOI-3 and Appendix D, Sections III.A.1.iv and III.A.2.v for AOI-4A. For AOI-4A, applicants are also encouraged to provide letters of commitment or interest for the proposed CO_2 source, CO_2 conversion, and/or CO_2 geologic storage locations.

Save this information in a single file named “CIL.pdf” and click on “Add Optional Other Attachment” to attach.

xxxv. Regulatory Plan Analysis (AOI-4A Only)

Only required for AOI-4A.

Applicants are required to submit a Regulatory Plan Analysis of the proposed project in accordance with the requirements and format provided in Appendix D, Section III.C and Appendix Y. Save this information in a single file named “RPA.pdf” and click on “Add Optional Other Attachment” to attach.

C. Post Selection Information Requests (April 2023)

If selected for award negotiations, DOE reserves the right to require that selected applicants provide additional or clarifying information regarding the application submissions, the project, the project team, the award requirements, and any other matters related to anticipated award. The following is a non-exhaustive list of examples of information that may be required:

- Personnel proposed to work on the project and collaborating organizations (See Section VI, “Award Administration Information; Participants and Collaborating Organizations”);
- Current and Pending Support (See Section VI, “Award Administration Information; Current and Pending Support”);
- Indirect cost information;
- Other budget information;
- Name and phone number of the Designated Responsible Employee for complying with national policies prohibiting discrimination (See 10 CFR 1040.5);
- Listing of Protected Data and Unlimited Rights Data, if applicable;
- Representation of Limited Rights Data and Restricted Software, if applicable;
- Updated Commitment Letters from Third Parties Contributing to Cost Share, if applicable;
- Updated Environmental Questionnaire, if applicable;
- Foreign National Participation;
- Information for the DOE Office of Civil Rights to process assurance reviews under 10 CFR 1040;

D. Submission Dates and Times

Full Applications must be received no later than the time/dates provided on the cover page of this FOA. **APPLICATIONS RECEIVED AFTER THE DEADLINE WILL NOT BE REVIEWED OR CONSIDERED FOR AWARD.**

E. Intergovernmental Review

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

F. Other Submission and Registration Requirements

i. Registration Process

There are several one-time actions before submitting an application in response to this FOA, and it is vital that applicants address these items as soon as possible. Some may take several weeks, and failure to complete them could interfere with an applicant's ability to apply to this FOA, or to meet the negotiation deadlines and receive an award if the application is selected. These requirements are provided immediately following the FOA cover page or modification summary, if applicable.

ii. Where to Submit

You cannot submit an application through Grants.gov unless you are registered. Please read the registration requirements carefully and start the process immediately. **Applications submitted via e-mail will not be accepted.**

Grants.gov applicants can apply online using Workspace. Workspace is a shared, online environment where members of a grant team may simultaneously access and edit different webforms within an application. For each funding opportunity announcement (FOA), you can create individual instances of a workspace.

Below is an overview of submitting an application using Workspace on Grants.gov. For access to complete instructions on how to apply for opportunities using Workspace, refer to: https://www.grants.gov/web/grants/applicants/workspace-overview.html

1) *Create a Workspace*: Creating a workspace allows you to complete it online and route it through your organization for review before submitting.

2) *Complete a Workspace*: Add participants to the workspace to work on the application together, complete all the required forms online or by downloading PDF versions, and check for errors before submission. The Workspace progress bar will display the state of your application process as you apply. As you apply using Workspace, you may click the blue question mark icon near the upper-right corner of each page to access context-sensitive help.
    a. *Adobe Reader*: If you decide not to apply by filling out webforms you can download individual PDF forms in Workspace. The individual PDF forms can be downloaded and saved to your local device storage, network drive(s), or external drives, then accessed through Adobe Reader. NOTE: Visit the Adobe Software Compatibility page on Grants.gov to download the appropriate version of the software at: https://www.grants.gov/web/grants/applicants/adobe-software-compatibility.html
    b. *Mandatory Fields in Forms:* In the forms, you will note fields marked with an asterisk and a different background color. These fields are mandatory fields that must be completed to successfully submit your application.
    c. *Complete SF-424 Fields First:* The forms are designed to fill in common required fields across other forms, such as the applicant name, address, and UEI. Once it is completed, the information will transfer to the other forms.
3) *Submit a Workspace:* An application may be submitted through workspace by clicking the Sign and Submit button on the Manage Workspace page, under the Forms tab. Grants.gov recommends submitting your application package at least 24-48 hours prior to the close date to provide you with time to correct any potential technical issues that may disrupt the application submission.
4) *Track a Workspace Submission:* After successfully submitting a workspace application, a Grants.gov Tracking Number (GRANTXXXXXXXX) is automatically assigned to the application. The number will be listed on the Confirmation page that is generated after submission. Using the tracking number, access the Track My Application page under the Applicants tab or the Details tab in the submitted workspace.

For additional training resources, including video tutorials, refer to: https://www.grants.gov/web/grants/applicants/applicant-training.html
Applicant Support: Grants.gov provides applicants 24/7 support via the toll-free number 1-800-518-4726 and email at support@grants.gov. For

questions related to the specific grant opportunity, contact the number listed in the application package of the grant you are applying for.
If you are experiencing difficulties with your submission, it is best to call the Grants.gov Support Center and get a ticket number. The Support Center ticket number will assist the DOE with tracking your issue and understanding background information on the issue.

iii. Full Application Proof of Timely Submissions

Proof of timely submission is automatically recorded by Grants.gov. An electronic date/time stamp is generated within the system when the application is successfully received by Grants.gov. The applicant with the AOR role who submitted the application will receive an acknowledgement of receipt and a tracking number (GRANTXXXXXXXX) from Grants.gov with the successful transmission of their application. The applicant with the AOR role will also receive the official date/time stamp and Grants.gov Tracking number in an email serving as proof of their timely submission. The Grants.gov Support Center reports that some applicants end the transmission because they think that nothing is occurring during the transmission process. Please be patient and give the system time to process the application.

When DOE successfully retrieves the application from Grants.gov, and acknowledges the download of submissions, Grants.gov will provide an electronic acknowledgment of receipt of the application to the email address of the applicant with the AOR role who submitted the application. Again, proof of timely submission shall be the official date and time that Grants.gov receives your application. Applications received by Grants.gov after the established due date for the FOA will be considered non-compliant.

iv. Electronic Authorization of Applications and Award Documents

Submission of an application and supplemental information under this FOA through electronic systems used by the DOE, including Grants.gov and FedConnect.net, constitutes the authorized representative's approval and electronic signature.

G. Funding Restrictions (April 2023)

Funding for all awards and future budget periods are contingent upon the availability of funds appropriated by Congress for the purpose of this program and the availability of future-year budget authority.

Costs must be allowable, allocable and reasonable in accordance with the applicable federal cost principles referenced in 2 CFR part 200 as amended by 2 CFR part 910. Pursuant to 2 CFR 910.352, the cost principles in the Federal Acquisition Regulations (48 CFR 31.2) apply to for-profit entities. The cost principles contained in 2 CFR Part 200, Subpart E apply to all entities other than for-profits.

H. Pre-Award Costs

Recipients may charge to an award resulting from this announcement pre-award costs that were incurred within the ninety (90) calendar day period immediately preceding the effective date of the award, if the costs are allowable in accordance with the applicable Federal cost principles referenced in 2 CFR part 200 as amended by 2 CFR part 910 [DOE Financial Assistance Regulation]. Recipients must obtain the prior approval of the contracting officer for any pre-award costs that are for periods greater than this 90-day calendar period.

Pre-award costs are incurred at the applicant's risk. DOE is under no obligation to reimburse such costs if for any reason the applicant does not receive an award or if the award is made for a lesser amount than the applicant expected.

I. Pre-Award Costs Related to National Environmental Policy Act (NEPA) Requirements

DOE's decision whether and how to distribute Federal funds under this FOA is subject to NEPA. Applicants should carefully consider and should seek legal counsel or other expert advice before taking any action related to the proposed project that would have an adverse effect on the environment or limit the choice of reasonable alternatives prior to DOE completing the NEPA review process.

DOE does not guarantee or assume any obligation to reimburse pre-award costs incurred prior to receiving written authorization from the Contracting Officer. If the applicant elects to undertake activities that DOE determines may have an adverse effect on the environment or limit the choice of reasonable alternatives prior to receiving such written authorization from the Contracting Officer, the applicant is doing so at risk of not receiving Federal funding for the project and such costs may not be recognized as allowable cost share. Nothing contained in the pre-award cost reimbursement regulations or any pre-award costs approval letter from the Contracting Officer override these NEPA requirements to obtain the written authorization from the Contracting Officer prior to taking any action that may have an adverse effect on the environment or limit the choice of reasonable alternatives. Likewise, if a project is selected for negotiation of award, and the Prime Recipient elects to undertake activities that are not authorized for Federal funding by the Contracting Officer in advance of DOE completing a NEPA review, the Prime

Recipient is doing so at risk of not receiving Federal Funding and such costs may not be recognized as allowable cost share.

J. Performance of Work in the United States (Foreign Work Waiver) (April 2023)

i. Requirement

All work performed under DOE awards issued under this FOA must be performed in the United States. The prime recipient must flow down this requirement to its subrecipients.

ii. Failure to Comply

If the prime recipient fails to comply with the Performance of Work in the United States requirement, DOE may deny reimbursement for the work conducted outside the United States and such costs may not be recognized as allowable recipient cost share. The prime recipient is responsible should any work under this award be performed outside the United States, absent a waiver, regardless of whether the work is performed by the prime recipient, subrecipients, contractors or other project partners.

iii. Waiver

To seek a foreign work waiver, the applicant must submit a written waiver request to DOE. The "Waiver Requests: Foreign Entity Participation and Performance of Work in the United States" Appendix lists the information that must be included in a request for a foreign work waiver.

It is noted that direct labor associated with foreign travel to attend or present at a scientific/technical conference or consortium that has been approved by DOE does not require a waiver.

K. Foreign Travel

If international travel is proposed for your project, please note that your organization must comply with the International Air Transportation Fair Competitive Practices Act of 1974 (49 USC 40118), commonly referred to as the "Fly America Act," and implementing regulations at 41 CFR 301-10.131 through 301-10.143. The law and regulations require air transport of people or property to, from, between, or within a country other than the United States, the cost of which is supported under this award, to be performed by or under a cost-sharing arrangement with a U.S. flag carrier, if service is available.

L. Equipment and Supplies

Property disposition may be required at the end of a project if the current fair market value of property exceeds $5,000. For-profit entity disposition requirements are set forth at 2 CFR 910.360. Property disposition requirements for other non-Federal entities are set forth in 2 CFR 200.310 – 200.316. However, pursuant to the FY23 Consolidated Appropriations Act (Pub. L. No. 117-328), Division D, Title III, Section 309, the Secretary, or a designee of the Secretary may, at their discretion, vest unconditional title or other property interests acquired under this project regardless of the fair market value of the property at the end of the award period.

M. Build America Buy America Requirements for Infrastructure Projects

Pursuant to the Build America Buy America Act, subtitle IX of BIL (Buy America, or "BABA"), and in accordance with 2 CFR Part 184, no funds for federalf financial assistanceance which is subject to BABA requirements may be used for a project unless:

- All ironsteel used in the infrastructure work are produced in the United States;
- All manufactured products used in the project are produced in the United States; and
- All construction materials used in the infrastructure work are manufactured in the United States.

Whether a given project must apply this requirement is project-specific and dependent on several factors, such as the recipient's entity type, whether the work involves "infrastructure," as that term is defined in Section 70914 of the Bipartisan Infrastructure Law, and whether the infrastructure in question is publicly owned or serves a public function.

Applicants are strongly encouraged to consult Appendix D of this FOA to determine whether their project may have to apply this requirement, both to make an early determination as to the need of a waiver, as well as to determine what impact, if any, this requirement may have on the proposed project's budget.

BABA requirements apply to DOE prime recipients that are "non-Federal entities". In accordance with OMB Memorandum M-24-02 and 2 CFR 200.1, the term "non-Federal ," includes statesincludesss, local governments, territories,

Indian TribesTs, Institution of Higher Education, or nonprofit organizations. DOE does not apply BABA requirements to for-profit entities.

Subawards should conform to the terms of the prime award from which they flow; in other words, for-profit prime recipients are not required to flow down these Buy America requirements to subrecipients, even if those subrecipients are non-Federal entities as defined above. Conversely, prime recipients which are non-Federal entities must flow the Buy America requirements down to all subrecipients, even if those subrecipients are for-profit entities.

The DOE financial assistance agreement will require each recipient to: (1) fulfill the commitments made in its application regarding the procurement of U.S.-produced products and (2) fulfill the commitments made in its application regarding the procurement of other key component metals and manufactured products domestically that are deemed available in sufficient and reasonably available quantities or of a satisfactory quality at the time of award negotiation. Applicants may seek waivers of these requirements in very limited circumstances and for good cause shown. Further details on requesting a waiver can be found in Appendix G and the terms and conditions of an award

Applicants are strongly encouraged to consult Appendix D and 2 CFR Part 184 for more information.

V. Application Review Information

A. Review Criteria

i. Compliance/Responsiveness Review

Prior to a comprehensive merit evaluation, DOE will (1) perform a compliance review to determine that submissions are timely and the information required by the FOA has been submitted (form and content requirements); and (2) perform a responsiveness review to determine that the Applicant is eligible for an award and the proposed project is responsive to the objectives of the FOA. Applications that fail the compliance and responsiveness review will not be forwarded for merit review and will be eliminated from further consideration.

ii. Full Application Merit Review Criteria

The following evaluation criteria will be utilized by the Technical Evaluation Committee and Federal Merit Review Panel members in conducting their evaluations of applications subjected to comprehensive merit review.

Criterion 1: Scientific and Technological Merit (40%)

AOIs-1 and AOI-3

- Thoroughness of the description of the proposed technology, methodology, or resource and degree to which the proposed technology, methodology, or resource meets the stated objectives and success metrics of the FOA and the relevant AOI. Completeness of the description of process chemistry, kinetics, thermodynamics, cycle, and operating conditions.

- Thoroughness of the Technology Competitive Assessment. Degree to which the Applicant comprehensively advances arguments and provides details that clearly distinguishes the proposed R&D and why it is needed now relative to prior work.

- Relevance of the proposed technology, methodology, or resource, as supported with experimental results from the applicant's previous and active research corresponding to the AOI addressed. Footnotes and the bibliography are only to be utilized to validate the information contained in the narrative.
- Feasibility of the proposed concept, project, or resource; the degree to which the proposed work is based on sound scientific and engineering principles.

- Thoroughness and completeness of the identification of knowledge gaps and key technical challenges.

- Extent to which the application provides evidence that the proposed technology or methodology has achieved the minimum required starting TRL.

- Adequacy and completeness of Risk Assessment Analysis, including identification of major technical risks and thoroughness of discussion on how the proposed project will mitigate those risks.

- Thoroughness and completeness of the State Point Data Table.

- Adequacy of the preliminary TEA to meet FOA objectives and degree to which a complete description of the TEA was provided. If applicable, quality and completeness of the preliminary TEA of the product in its intended end use application, including (1) market size, (2) required

selling price of the product, (3) gross revenue, (4) predicted compound annual growth rate (CAGR) of the market, and (5) potential CO_2 mitigation potential.

- Adequacy of the preliminary LCA to meet FOA objectives and degree to which a complete description of the LCA was provided. If applicable, potential to lower carbon intensity as compared to a business-as-usual base case.

Additional AOI-1F Crierion 1

- Degree to which the preliminary TEA shows progress towards a 30% reduction in cost of product via RCC technology versus a reference conventional process with sequential capture and conversion.

- Degree to which the preliminary life cycle analysis (LCA) shows carbon neutral production for atmospheric RCC, or progress toward carbon neutral production for RCC utilizing CO2 from exhaust flue gas streams.

- Degree to which the proposed technology utilizes CO2 in the product, including carbon uptake and carbon efficiency. Adequacy of methods to foster CO2 adsorption and absorption.

Additional AOI-3F and AOI-3G Criterion 1

- Thoroughness of the discussion regarding portability of the proposed testing unit, including projected size, configuration of various unit operations, and flexibility of connections to the currently proposed host site and potential host sites for future testing.

- Strength of justification if the applicant chooses to propose a non-portable test unit for AOI 3F.

- Adequacy of the summary description and validation of the process model.

Additional AOI-3H Criterion 1

- Adequacy and completeness of information provided in the summary of the preliminary TEA, including mass and energy balances, estimates of heating and cooling duties and electric power requirements covering the carbon capture system and balance-of-plant, cost of capture, and levelized cost of product or LCOE.

- Degree to which the Applicant provided a complete description of the host plant, how the carbon capture technology will be integrated within the host site, and how and why the selected host site was chosen.

- The likelihood that development of this concept will result in a successful deployment at proposed scale.

- Adequacy of the description and validation of the process model to be used as the basis for the pre-FEED study.

- Adequacy and completeness of information provided in the summary of the preliminary LCA to meet FOA objectives. The degree to which the proposed carbon capture technology will have a positive life-cycle impact such as reducing greenhouse gas emissions, criteria pollutants, water usage, and other environmental considerations across the full life cycle compared to current/conventional technologies and processes.

- Thoroughness and completeness of the preliminary Business Case Analysis (BCA).

AOI-4A Criterion 1

- The degree to which the applicant addresses the transfer facility site selection requirements in Appendix D, Section III.A.1.i-iii.

- Provision of, at minimum, a commitment letter for the proposed multimodal transfer facility host site as described in Appendix D, Section III.A.1.iv.

- Thoroughness, completeness, and adequacy of the identification of proposed CO_2 source(s) as described in Appendix D, Section III.A.2.i and, if applicable, Appendix D, Section III.A.2.iv.

- Thoroughness, completeness, and adequacy of the identification of proposed CO_2 sinks as described in Appendix D, Section III.A.2.ii and, if applicable, Appendix D, Section III.A.2.iv.

- Thoroughness, completeness, and adequacy of the identification of proposed CO_2 connective transport infrastructure site as described in Appendix D, Section II.A.2.iii and, if applicable, Appendix D, Section III.A.2.iv.

- Thoroughness, completeness, and adequacy of the transfer facility design as described in Appendix D, Section III.A.3.

- Thoroughness and completeness of the risk assessment and HSE analysis as described in Appendix D, Section III.A.4.

- Thoroughness and completeness of the transfer facility cost estimate as described in Appendix D, Section III.A.5.

- Soundness of the description of the proposed effort and approach to completing the business case as described in Appendix D, Section III.B.

- Thoroughness, completeness, and adequacy of the regulatory plan analysis as described in Appendix D, Section III.C.

Criterion 2: Technical Approach and Understanding (30%)

All AOIs

- Adequacy and feasibility of the Applicant's approach to achieving the objectives of the FOA and the relevant AOI.

- The degree to which the proposed work is based on sound scientific and engineering principles.

- Feasibility, appropriateness, rationale, and completeness of the proposed Statement of Project Objectives, such that there is a logical progression of work to reduce the identified project risk and inclusion of appropriate and relevant SMART milestones and Go/No Go decision points.

- The adequacy and completeness of the Project Management Plan (PMP) in establishing baselines (technical scope, budget, schedule), performance metrics that will be assessed during the proposed R&D project and in managing project performance relative to those baselines; defining the actions that will be taken when these baselines must be revised; and identification of project risks and strategies for mitigation.

- Extent to which the Data Management Plan outlines the proposed plan for data sharing or preservation.

Criterion 3: Technical and Management Capabilities (20%)

All AOIs

- Demonstrated experience of the Applicant and partnering organizations in the technology, methods, and resource areas addressed in the application and in managing projects of similar size, scope, and complexity.

- Credentials, capabilities, availability and experience of key personnel and partnering organizations.

- Clarity and likely effectiveness of the project organization, including sub-recipients or partners, to successfully complete the project.

- Adequacy and availability of proposed personnel, facilities, and equipment to perform project tasks.

Additional AOI-3F and AOI-3G Criterion 3

- Adequacy of proposed team structure that includes industrial facility or NGPP owner/operator and carbon capture technology developer.

- Demonstrated adequacy and commitment of the proposed host site to support the pilot testing.

Additional AOI 3H-a Criterion 3

- Adequacy of proposed team structure that includes NGPP owner/operator; carbon capture technology developer; and engineering, procurement and construction (EPC) engineering firm.

- Demonstrated adequacy and commitment of the proposed host site to support the pre-FEED study.

Criterion 4: Community Benefits Plan (10**%)**

Diversity, Equity, Inclusion, and Accessibility (DEIA)

- Clear articulation of the project's goal related to diversity, equity, inclusion, and accessibility.

- Quality of the project's DEIA goals, as measured by the goals' depth, breadth, likelihood of success, inclusion of appropriate and relevant SMART milestones, and overall project integration.

- Degree of applicant's commitment and ability to track progress towards meeting each of the diversity, equity, inclusion, and accessibility goals.

- Extent of engagement of organizations that represent underserved communities as a core element of their mission, including MSIs, Minority Business Entities, and non-profit or community-based organizations.

Energy Equity

- Clear workplan tasks, staffing, research, and timeline for engaging energy equity stakeholders and/or evaluating the possible near and long-term implications of the project for the benefit of the American public; including but not limited to the public health and public prosperity benefits.

- Approach, methodology, and expertise articulated in the plan for addressing energy equality and justice issues associated with the technology innovation.

- Likelihood that the plan will result in improved understanding of distributional public benefits and costs related to the innovation if successful.

Workforce Implications

- Clear and comprehensive workplan tasks, staffing, research, and timeline for engaging workforce stakeholders and/or evaluating the possible near and long-term implications of the project for the United States workforce.

- Approach to document the knowledge, skills, and abilities of the workforce required for successful commercial deployment of innovations resulting from this research.

- Likelihood that the plan will result in improved understanding of the workforce implications related to the innovation if successful.

B. Other Selection Factors

i. Program Policy Factors

In addition to the above criteria, the Selection Official may consider the following program policy factors in determining which Full Applications to select for award negotiations:

- It may be desirable to select for award a project, or group of projects, that represent a diversity of technical approaches, methods, and resources under this FOA or the overall program.

- It may be desirable to support complementary and/or similar projects which, when taken together, will best achieve the program's research goals and objectives.

- It may be desirable that different kinds and sizes of organizations be selected for award in order to provide a balanced programmatic effort and a variety of technical perspectives under this FOA or the overall program. For example, it may be desirable to select a project, or group of projects, that exhibit team member diversity, with participants including but not limited to those from MSIs (e.g., HBCUs/OMIs)[5].

- In order to best achieve the program's research goals and objectives, it may be desirable to select for award a project or group of projects with a broad or specific geographic distribution under this FOA or the overall program.

- It may be desirable to select a project, or group of projects, if such a selection will optimize use of available funds.

- It may be desirable to select a project, or group of projects, if such a selection presents lesser schedule risk, lesser budget risk, lesser technical risk, lesser societal considerations and impacts risk, and/or lesser environmental risks. Environmental risk includes, but is not limited to, an adverse impact to air, soil, water, or increase in overall cradle-to-grave greenhouse gas footprint (carbon dioxide equivalent, CO_2e).

- It may be desirable to select an entity located in an urban and economically distressed area including a Qualified Opportunity Zone (QOZ) or to select a project, or group of projects, if the proposed project(s) will occur in a QOZ or otherwise advance the goals of a QOZ, including spurring economic development and job creation in distressed communities throughout the United States.

[5] Minority Serving Institutions (MSIs), including HBCUs/OMIs as educational entities recognized by the Office of Civil Rights (OCR), U.S. Department of Education, and identified on the OCR's Department of Education U.S. accredited postsecondary minorities' institution list. See https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html.

- It may be desirable to select for award a project, or group of projects, that represent a diversity of carbon dioxide (CO_2) sources under this FOA or the overall program.

- The degree to which the proposed project will employ procurement of U.S. iron, steel, manufactured products, and construction materials.

- The degree to which the proposed project, when compared to the existing DOE project portfolio and other projects to be selected from the subject FOA, contributes to the total portfolio meeting the goals reflected in the Community Benefits Plan criteria.

C. Other Review Requirements

i. Risk Assessment

Pursuant to 2 CFR 200.206, DOE will conduct an additional review of the risk posed by applications submitted under this FOA. Such risk assessment will consider:

1. Financial stability;
2. Quality of management systems and ability to meet the management standards prescribed in 2 CFR Part 200 as adopted and supplemented by 2 CFR Part 910;
3. History of performance;
4. Audit reports and findings; and
5. The applicant's ability to effectively implement statutory, regulatory, or other requirements imposed on non-federal entities.

DOE may make use of other publicly available information and the history of an applicant’s performance under DOE or other federal agency awards.

Depending on the severity of the findings and whether the findings were resolved, DOE may elect not to fund the applicant.

In addition to this review, DOE must comply with the guidelines on government-wide suspension and debarment in 2 CFR Part 180 and must require non-federal entities to comply with these provisions. These provisions restrict federal awards, subawards and contracts with certain parties that are debarred, suspended or otherwise excluded from or ineligible for participation in federal programs or activities.

Further, as DOE invests in critical infrastructure and funds critical and emerging technology areas, DOE also considers possible vectors of undue foreign influence

in evaluating risk. If high risks are identified and cannot be sufficiently mitigated, DOE may elect to not fund the applicant. As part of the research, technology, and economic security risk review, DOE may contact the applicant and/or proposed project team members for additional information to inform the review. This risk review is conducted separately from the technical merit review.

ii. Recipient Responsibility and Qualifications (May 2023)

DOE, prior to making a Federal award with a total amount of Federal share greater than the simplified acquisition threshold, is required to review and consider any responsibility and qualification information about the applicant that is in entity information domain in SAM.gov (see 41 U.S.C. 2313).

The applicant, at its option, may review information in the entity information domain in SAM.gov and comment on any information about itself that a federal awarding agency previously entered and is currently in the entity information domain in SAM.gov.

DOE will consider any written comments by the applicant, in addition to the other information in the entity information domain in SAM.gov, in making a judgment about the applicant's integrity, business ethics, and record of performance under Federal awards when completing the review of risk posed by applicants as described in 2 CFR 200.206 - Federal awarding agency review of risk posed by applicants.

D. Review and Selection Process

i. Overview

The evaluation process consists of multiple phases; each includes an initial eligibility review and a thorough technical review. Rigorous technical reviews of eligible submissions are conducted by reviewers that are experts in the subject matter of the FOA. Ultimately, the Selection Official considers the recommendations of the reviewers, along with other considerations such as program policy factors and risk reviews, in determining which applications to select.

ii. Pre-Selection Clarification

DOE may determine that pre-selection clarifications are necessary from one or more applicants. Pre-selection clarifications are distinct from and less formal than pre-selection interviews. These pre-selection clarifications will solely be for the purposes of clarifying the application. The pre-selection

clarifications may occur before, during or after the merit review evaluation process. Information provided by an applicant that is not necessary to address the pre-selection clarification question will not be reviewed or considered. Typically, a pre-selection clarification will be carried out through either written responses to DOE's written clarification questions or video or conference calls with DOE representatives.

The information provided by applicants to DOE through pre-selection clarifications is incorporated in their applications and contributes to the merit review evaluation and DOE's selection decisions. If DOE contacts an applicant for pre-selection clarification purposes, it does not signify that the applicant has been selected for negotiation of award or that the applicant is among the top ranked applications.

DOE will not reimburse applicants for expenses relating to the pre-selection clarifications, nor will these costs be eligible for reimbursement as pre-award costs.

iii. Merit Review

Applications that pass the compliance/responsiveness review will be subjected to a merit review in accordance with the Merit Review Criteria listed in the FOA and the guidance provided in the "Merit Review Guide for Financial Assistance and Unsolicited Proposals." This guide is available at https://energy.gov/management/financial-assistance.

iv. Selection

The Selection Official may consider the merit review, program policy factors, and the amount of funds available in arriving at selections for this FOA.

v. Discussions and Award

The Government may enter into discussions with a selected applicant for any reason deemed necessary, including but not limited to: (1) the budget is not appropriate or reasonable for the requirement; (2) only a portion of the application is selected for award; (3) the Government needs additional information to determine that the recipient is capable of complying with the requirements in 2 CFR part 200 as amended by 2 CFR part 910 [DOE Financial Assistance Regulation]; and/or (4) special terms and conditions are required. Failure to resolve satisfactorily the issues identified by the Government will preclude award to the applicant.

VI. Award Administration Information

A. Notices

i. Ineligible Submissions

Ineligible Full Applications will not be further reviewed or considered for award. The Contracting Officer will send a notification letter by email to the technical and administrative points of contact designated by the applicant in Grants.gov. The notification letter will state the basis upon which the Full Application is ineligible and not considered for further review.

ii. Full Application Notifications

DOE will notify applicants of its determination via a notification letter by email to the technical and administrative points of contact designated by the applicant in Grants.gov. The notification letter will inform the applicant whether or not its Full Application was selected for award negotiations. Alternatively, DOE may notify one or more applicants that a final selection determination on particular Full Applications will be made at a later date, subject to the availability of funds or other factors.

(a) Successful Applicants

Receipt of a notification letter selecting a Full Application for award negotiations does not authorize the applicant to commence performance of the project. If an application is selected for award negotiations, it is not a commitment by DOE to issue an award. Applicants do not receive an award until award negotiations are complete and the Contracting Officer executes the funding agreement, accessible by the Prime Recipient in FedConnect.

The award negotiation process may take up to 60 days. Applicants must designate a primary and a backup point-of-contact in Grants.gov with whom DOE will communicate to conduct award negotiations. The applicant must be responsive during award negotiations (i.e., provide requested documentation) and meet the negotiation deadlines. If the applicant fails to do so or if award negotiations are otherwise unsuccessful, DOE will cancel the award negotiations and rescind the Selection. DOE reserves the right to terminate award negotiations at any time for any reason.

Please refer to Section IV, "Application and Submission Information; Pre-Award Costs" of the FOA for guidance on pre-award costs.

(b) Unsuccessful Applicants

DOE shall promptly notify in writing each applicant whose application has not been selected for negotiation or award. This notice will explain why the application was not selected.

(c) Alternate Selection Determinations

In some instances, an applicant may receive a notification that its application was not selected for award and DOE designated the application to be an alternate. As an alternate, DOE may consider the Full Application for Federal funding in the future. A notification letter stating the Full Application is designated as an alternate does not authorize the applicant to commence performance of the project. DOE may ultimately determine to select or not select the Full Application for award negotiations.

(d) Notice of Award

An Assistance Agreement issued by the Contracting Officer is the authorizing award document. It normally includes either as an attachment or by reference: (1) Special Terms and Conditions; (2) Applicable program regulations, if any; (3) Application, which includes the project description and budget, as approved by DOE; (4) 2 CFR part 200 as amended by 2 CFR part 910; (5) National Policy Assurances To Be Incorporated As Award Terms; (6) Budget Summary; (7) Federal Assistance Reporting Checklist and Instructions, which identifies the reporting requirements; (8) Intellectual Property; (9) Federal-wide Research Terms and Conditions; (10) Agency Specific Requirements; and (11) any award specific terms and conditions.

B. Administrative and National Policy Requirements

i. Award Administrative Requirements

The administrative requirements for DOE grants and cooperative agreements are contained in 2 CFR Part 200 as amended by 2 CFR Part 910.

DOE Special Terms and Conditions for Use in Most Grants and Cooperative Agreements. The DOE Special Terms and Conditions for Use in Most Grants

and Cooperative Agreements are located at https://www.energy.gov/management/financial-assistance-forms-and-information-applicants-and-recipients under Award Terms.

National Policy Requirements. The National Policy Assurances that are incorporated as a term and condition of award are located at: https://www.energy.gov/management/financial-assistance-forms-and-information-applicants-and-recipients.

Intellectual Property Provisions. The standard DOE financial assistance intellectual property provisions applicable to the various types of recipients are located at: https://energy.gov/gc/standard-intellectual-property-ip-provisions-financial-assistance-awards.

ii. Unique Entity Identifier Requirements and System for Award Management (April 2023)

Each applicant (unless the applicant is an individual or federal awarding agency that is excepted from those requirements under 2 CFR 25.110(b) or (c), or has an exception approved by the federal awarding agency under 2 CFR 25.110(d)) is required to: (1) Be registered in the SAM at https://www.sam.gov before submitting its application; (2) provide a valid UEI number in its application; and (3) continue to maintain an active SAM registration with current information at all times during which it has an active federal award or an application or plan under consideration by a federal awarding agency. DOE may not make a federal award to an applicant until the applicant has complied with all applicable UEI and SAM requirements and, if an applicant has not fully complied with the requirements by the time DOE is ready to make a federal award, the DOE will determine that the applicant is not qualified to receive a federal award and use that determination as a basis for making a federal award to another applicant.

NOTE: Due to the high demand of UEI requests and SAM registrations, entity legal business name and address validations are taking longer than expected to process. Entities should start the UEI and SAM registration process as soon as possible. If entities have technical difficulties with the UEI validation or SAM registration process, they should utilize the **HELP** feature on **SAM.gov**. SAM.gov will work entity service tickets in the order in which they are received and asks that entities not create multiple service tickets for the same request or technical issue. Additional entity validation resources can be found here: GSAFSD Tier 0 Knowledge Base - Validating your Entity**.**

iii. Uniform Commercial Code (UCC) Financing Statements

Per 2 CFR 910.360 (Real Property and Equipment) when a piece of equipment is purchased by a for-profit recipient or subrecipient with Federal Funds (federal and/or non-federal), and when the Federal share of the financial assistance agreement is more than $1,000,000, the recipient or subrecipient must:

Properly record, and consent to the Department's ability to properly record if the recipient fails to do so, Uniform Commercial Code (UCC) financing statement(s) for all equipment in excess of $5,000 purchased with project funds. These financing statement(s) must be approved in writing by the contracting officer prior to the recording, and they shall provide notice that the Recipient's title to all equipment (not real property) purchased with Federal funds under the financial assistance agreement is conditional pursuant to the terms of this section, and that the Government retains an undivided reversionary interest in the equipment. The UCC financing statement(s) must be filed before the Contracting Officer may reimburse the recipient for the Federal share of the equipment unless otherwise provided for in the relevant financial assistance agreement. The recipient shall further make any amendments to the financing statements or additional recordings, including appropriate continuation statements, as necessary or as the contracting officer may direct.

Note: All costs associated with filing UCC financing statements, UCC financing statement amendments, and UCC financing statement terminations, are allowable and allocable costs to be charged to the Federal award.

iv. Foreign National Participation (April 2023)

All applicants selected for an award under this FOA and project participants (including subrecipients and contractors) who anticipate involving foreign nationals in the performance of an award, will be required to provide DOE with specific information about each foreign national to satisfy requirements for foreign national participation and access approvals. The volume and type of information collected may depend on various factors associated with the award. DOE concurrence may be required before a foreign national can participate in the performance of any work under an award.

Approval for foreign nationals in Principal Investigator/Co-Investigator roles, from countries of risk (i.e., China, Iran, North Korea and Russia), or from countries identified on the U.S. Department of State's list of State Sponsors of Terrorism (https://www.state.gov/state-sponsors-of-terrorism/) may

require written authorization from DOE before they can participate in the performance of any work under an award.

A “foreign national” is defined as any person who is not a United States citizen by birth or naturalization. DOE may elect to deny foreign national’s participation in the award. Likewise, DOE may elect to deny a foreign national’s access to a DOE sites, information, technologies, equipment, programs, or personnel.

Applicants selected for award negotiations must include this requirement in subawards.

v. Export Control

The United States government regulates the transfer of information, commodities, technology, and software considered to be strategically important to the United States to protect national security, foreign policy, and economic interests without imposing undue regulatory burdens on legitimate international trade. There is a network of federal agencies and regulations that govern exports that are collectively referred to as “Export Controls”. All recipients and subrecipients are responsible for ensuring compliance with all applicable United States Export Control laws and regulations relating to any work performed under a resulting award.

The recipient must immediately report to DOE any export control investigations, indictments, charges, convictions, and violations upon occurrence, at the recipient or subrecipient level, and provide the corrective action(s) to prevent further violations.

vi. Statement of Federal Stewardship

DOE will exercise normal Federal stewardship in overseeing the project activities performed under DOE Awards. Stewardship Activities include, but are not limited to, conducting site visits; reviewing performance and financial reports; providing assistance and/or temporary intervention in usual circumstances to correct deficiencies that develop during the project; assuring compliance with terms and conditions; and reviewing technical performance after project completion to ensure that the project objectives have been accomplished.

vii. Statement of Substantial Involvement

Cooperative agreements will be awarded under this announcement. There will be substantial involvement between the DOE and the Recipient during performance of this Cooperative Agreement.

Recipient's Responsibilities. The Recipient is responsible for:

- Performing the activities supported by this award in accordance with the Project Management Plan, including providing the required personnel, facilities, equipment, supplies and services;

- Managing and controlling project activities in accordance with established processes and procedures to ensure tasks and subtasks are completed within schedule and budget constraints defined by the current Project Management Plan;

- Implementing an approach to identify, analyze, and respond to project risks that is commensurate with the complexity of the project;

- Defining and revising approaches and plans, submitting the plans to DOE for review, and incorporating DOE comments;

- As applicable, coordinating related project activities with subrecipients and external suppliers, including contractors, to ensure effective integration of all work elements;

- Attending annual project review meetings and reporting project status;

- Participating in peer review evaluations of the project, or peer review evaluations of the program that their project supports;

- Submitting technical reports and publicly releasable documents that incorporate DOE comments; and

- Presenting the project results at appropriate technical conferences or meetings as directed by the DOE Project Officer.

DOE Responsibilities. DOE has the right to intervene in the conduct or performance of project activities for programmatic reasons. Intervention includes the interruption or modification of the conduct or performance of project activities. Suspension or termination of the cooperative agreement under 2 CFR part 200, as amended by 2 CFR part 910 (DOE Financial Assistance Regulations) does not constitute intervention in the conduct or performance of project activities.

DOE is responsible for:

- Reviewing in a timely manner project plans, including project management, testing and technology transfer plans, and recommending alternate approaches, if the plans do not address critical programmatic issues;

- Participating in project management planning activities, including risk analysis, to ensure DOE's program requirements or limitations are considered in performance of the work elements;

- Conducting annual project review meetings to ensure adequate progress and that the work accomplishes the program and project objectives. Recommending alternate approaches or shifting work emphasis, if needed;

- Providing substantial involvement to ensure that project results address critical system and programmatic goals established by the DOE Office of Fossil Energy and Carbon Management, in coordination with DOE's Point Source Carbon Capture, Carbon Dioxide Removal, Carbon Storage, or Carbon Conversion programs;

- Promoting and facilitating technology transfer activities, including disseminating program results through presentations and publications;

- Serving as scientific/technical liaison between awardees and other program or industry staff; and

- Reviewing and concurring with ongoing technical performance to ensure that adequate progress has been obtained within the current Budget Period authorized by DOE before work can commence on subsequent Budget Periods.

viii. Subject Invention Utilization Reporting

To ensure that prime recipients, subrecipients, and contractors holding title to subject inventions are taking the appropriate steps to commercialize subject inventions, DOE may require that each prime recipient holding title to a subject invention submit annual reports for 10 years from the date the subject invention was disclosed to DOE on the utilization of the subject invention and efforts made by prime recipient or its licensees or assignees to stimulate such utilization. The reports must include information regarding the status of development, date of first

commercial sale or use, gross royalties received by the prime recipient, and such other data and information as DOE may specify.

ix. Environmental Review in Accordance with National Environmental Policy Act (NEPA)

DOE's decision whether and how to distribute federal funds under this FOA is subject to the National Environmental Policy Act (42 USC 4321, *et seq.*). NEPA requires Federal agencies to integrate environmental values into their decision-making processes by considering the potential environmental impacts of their proposed actions. For additional background on NEPA, please see DOE's NEPA website, at http://nepa.energy.gov/.

While NEPA compliance is a Federal agency responsibility and the ultimate decisions remain with the Federal agency, all recipients selected for an award will be required to assist in the timely and effective completion of the NEPA process in the manner most pertinent to their proposed project. If DOE determines certain records must be prepared to complete the NEPA review process (e.g., biological evaluations or environmental assessments), the recipient may be required to prepare the records and the costs to prepare the necessary records may be included as part of the project costs.

x. Conference Spending

The recipient shall not expend **any** funds on a conference not directly and programmatically related to the purpose for which the grant or cooperative agreement was awarded that would defray the cost to the United States Government of a conference held by any Executive branch department, agency, board, commission, or office for which the cost to the United States Government would otherwise exceed $20,000, thereby circumventing the required notification by the head of any such Executive Branch department, agency, board, commission, or office to the Inspector General (or senior ethics official for any entity without an Inspector General), of the date, location, and number of employees attending such conference.

xi. Indemnity

Awards resulting from this FOA will contain the following provision reminding Recipients of DOE's rights of indemnification.

The Recipient shall indemnify the Government and its officers, agents, or employees for any and all liability, including litigation expenses and attorneys' fees, arising from suits, actions, or claims of any character for

death, bodily injury, or loss of or damage to property or to the environment, resulting from the project, except to the extent that such liability results from the direct fault or negligence of Government officers, agents or employees, or to the extent such liability may be covered by applicable allowable costs provisions.

xii. Go/No-Go Review

Each project selected under this FOA will be subject to a periodic project evaluation referred to as a Go/No-Go Review. At the Go/No-Go decision points, DOE will evaluate project performance, project schedule adherence, meeting milestone objectives, compliance with reporting requirements, and overall contribution to the DOE program goals and objectives. Federal funding beyond the Go/No Go decision point (continuation funding), is contingent on (1) the availability of funds appropriated by Congress for the purpose of this program; (2) the availability of future-year budget authority; (3) recipient's technical progress compared to the Milestone Summary Table stated in Attachment 1 of the award; (4) recipient's submittal of required reports; (5) recipient's compliance with the terms and conditions of the award; (6) DOE's Go/No-Go decision; (7) the recipient's submission of a continuation application; and (8) written approval of the continuation application by the Contracting Officer.

As a result of the Go/No Go Review, DOE may, at its discretion, authorize the following actions: (1) continue to fund the project, contingent upon the availability of funds appropriated by Congress for the purpose of this program and the availability of future-year budget authority; (2) recommend redirection of work under the project; (3) place a hold on federal funding for the project, pending further supporting data or funding; or (4) discontinue funding the project because of insufficient progress, change in strategic direction, or lack of funding.

The Go/No-Go decision is distinct from a non-compliance determination. In the event a recipient fails to comply with the requirements of an award, DOE may take appropriate action, including but not limited to, redirecting, suspending or terminating the award.

xiii. Interim Conflict of Interest Policy for Financial Assistance

The DOE interim Conflict of Interest Policy for Financial Assistance (COI Policy)[6] is applicable to all non-Federal entities applying for, or that receive,

[6] DOE's interim COI Policy can be found at PF 2022-17 FAL 2022-02 Department of Energy Interim Conflict of Interest Policy Requirements for Financial Assistance.

DOE funding by means of a financial assistance award (e.g., a grant, cooperative agreement, or technology investment agreement) and, through the implementation of this policy by the entity, to each Investigator who is planning to participate in, or is participating in, the project funded wholly or in part under the DOE financial assistance award. The term "Investigator" means the PI and any other person, regardless of title or position, who is responsible for the purpose, design, conduct, or reporting of a project funded by DOE or proposed for funding by DOE. Recipients must flow down the requirements of the interim COI Policy to any subrecipient non-Federal entities. Further, for DOE funded projects, the recipient must include all financial conflicts of interest (FCOI) (i.e., managed and unmanaged/ unmanageable) in their initial and ongoing FCOI reports.

It is understood that non-Federal entities and individuals receiving DOE financial assistance awards will need sufficient time to come into full compliance with DOE's interim COI Policy. To provide some flexibility, DOE allows for a staggered implementation. **Specifically, prior to award, applicants selected for award negotiations must: ensure all Investigators complete their significant financial disclosures; review the disclosures; determine whether a FCOI exists; develop and implement a management plan for FCOIs; and provide DOE with an initial FCOI report that includes all FCOIs (i.e., managed and unmanaged/ unmanageable).** Recipients will have 180 days from the date of the award to come into full compliance with the other requirements set forth in DOE's interim COI Policy. **Prior to award, the applicant must certify that it is, or will be within 180 days of the award, compliant with all requirements in the interim COI Policy.**

xiv. Participants and Collaborating Organizations

If selected for award negotiations, the selected applicant must submit a list of personnel who are proposed to work on the project, both at the recipient and subrecipient level and a list of proposed collaborating organizations within 30 days after the applicant is notified of the selection. Recipients will have an ongoing responsibility to notify DOE of changes to the personnel and collaborating organizations, and submit updated information during the life of the award.

xv. Current and Pending Support

If selected for award negotiations, within 30 days of the selection notice, the selectee must submit 1) current and pending support disclosures and resumes for any new PIs or senior/key personnel and 2) updated disclosures if there have been any changes to the current and pending support

submitted with the application. Throughout the life of the award, the Recipient has an ongoing responsibility to submit 1) current and pending support disclosure statements and resumes for any new PI and senior/key personnel and 2) updated disclosures if there are changes to the current and pending support previously submitted to DOE. Also See Section IV, "Application and Submission Information; Current and Pending Support".

xvi. Fraud, Waste and Abuse

The mission of the DOE Office of Inspector General (OIG) is to strengthen the integrity, economy and efficiency of the Department's programs and operations including deterring and detecting fraud, waste, abuse and mismanagement. The OIG accomplishes this mission primarily through investigations, audits, and inspections of DOE activities to include grants, cooperative agreements, loans, and contracts.

The OIG maintains a Hotline for reporting allegations of fraud, waste, abuse, or mismanagement. To report such allegations, please visit https://www.energy.gov/ig/ig-hotline.

Additionally, recipients of DOE awards must be cognizant of the requirements of 2 CFR § 200.113 Mandatory disclosures:

> The non-federal entity or applicant for a federal award must disclose, in a timely manner, in writing to the federal awarding agency or pass-through entity all violations of Federal criminal law involving fraud, bribery, or gratuity violations potentially affecting the federal award. Non-federal entities that have received a federal award including the term and condition outlined in appendix XII of 2 CFR Part 200 are required to report certain civil, criminal, or administrative proceedings to SAM. Failure to make required disclosures can result in any of the remedies described in § 200.339. (See also 2 CFR part 180, 31 U.S.C. 3321, and 41 U.S.C. 2313.) [85 FR 49539, Aug. 13, 2020]

Applicants/recipients and subrecipients (if applicable) are encouraged to allocate sufficient costs in the project budget to cover the costs associated for personnel and data infrastructure needs to support performance management and program evaluation needs including but not limited to independent program and project audits to mitigate risks for fraud, waste, and abuse.

xvii. Human Subjects Research

Research involving human subjects, biospecimens, or identifiable private information conducted with DOE funding is subject to the requirements of DOE Order 443.1C, Protection of Human Research Subjects, 45 CFR Part 46, Protection of Human Subjects (subpart A which is referred to as the "Common Rule"), and 10 CFR Part 745, Protection of Human Subjects.

Additional information on the DOE Human Subjects Research Program can be found at: HUMAN SUBJECTS Human Subjects Pr... | U.S. DOE Office of Science (SC) (osti.gov).

xviii. Program Down-Select

In addition to the Go/No-Go Reviews required for each project, DOE intends to conduct a competitive project review (down-selection process) upon the completion of AOI-1F, Phase 1. Recipients will present their projects to DOE individually (not to other recipients). Subject matter experts from academia, national laboratories, and industry may be used as reviewers, subject to conflict of interest and non-disclosure considerations. Projects will be evaluated based on the following criteria:

See Appendix A.

Upon completion of the competitive project review (down-selection process), DOE will select which projects will receive federal funding beyond AOI-1F, Phase 1. Due to the availability of funding and program considerations, only a portion of the recipients will be selected to receive funding for project continuation. As a result of this down-select process, certain projects will not receive federal funding beyond AOI-1F, Phase 1, even if the project is meeting the pre-defined metrics.

xix. Flood Resilience

Executive Order 11988, Floodplain Management, requires agencies engage in a decision-making process to evaluate the potential effects of any action it may take in a floodplain and to avoid development in a floodplain to the extent possible. DOE procedures for implementing the Executive Order are in 10 CFR Part 1022. Executive Order 13690, Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input (reinstated by EO 14030, Climate-Related Financial Risk), directs Federal agencies to "expand management from the current base flood level to a higher vertical elevation and corresponding horizontal floodplain to address current and future flood risk and ensure that projects funded with taxpayer dollars last as long as intended." The higher flood elevation is based on one of three approaches: climate-informed science (preferred), freeboard value,

or 0.2 percent annual flood change (500-year floodplain). Selectees will be required to indicate whether the proposed project location(s) is within a floodplain, how the floodplain was defined, and how the project's design has been modified to reduce the risk of flood loss and minimize the impact of floods on human safety, health, and welfare. Information to assist in the implementation of these requirements is available at:

- https://www.energy.gov/nepa/articles/eo-13690-establishing-federal-flood-risk-management-standard-and-process-further
- https://www.fema.gov/floodplain-management/intergovernmental/white-house-flood-resilience-interagency-working-group
- http://floodstandard.climate.gov

xx. Real Property and Equipment

Subject to the vesting of any property pursuant to Section 309 of the FY23 Consolidated Appropriations Act (Pub. L. No. 117-328), Division D, Title III, property disposition may be required at the end of a project if the current fair market value of property exceeds $5,000. For-profit entity disposition requirements are set forth at 2 CFR 910.360. Property disposition requirements for other non-federal entities are set forth in 2 CFR 200.310 – 200.316.

Real property and equipment purchased with project funds (federal share and recipient cost share) are subject to the requirements at 2 CFR 200.310, 200.311, 200.313, and 200.316 (non-Federal entities, except for-profit entities) and 2 CFR 910.360 (for-profit entities). For projects selected for award under this FOA, the recipient may (1) take disposition action on the real property and equipment; or (2) continue to use the real property and equipment after the conclusion of the award period of performance, with Contracting Officer approval.

The recipient's written Request for Continued Use must identify the property and include: a summary of how the property will be used (must align with the authorized project purposes); a proposed use period, (e.g., perpetuity, until fully depreciated, or a calendar date where the recipient expects to submit disposition instructions); acknowledgement that the recipient shall not sell or encumber the property or permit any encumbrance without prior written DOE approval; current fair market value of the property; and an Estimated Useful Life or depreciation schedule for equipment.

When the property is no longer needed for authorized project purposes, the recipient must request disposition instructions from DOE. For-profit entity

disposition requirements are set forth at 2 CFR 910.360. Property disposition requirements for other non-federal entities are set forth in 2 CFR 310-200.316. However, pursuant to the FY23 Consolidated Appropriations Act (Pub. L. No. 117-328), Division D, Title III, Section 309, the Secretary or a designee of the Secretary may, at their discretion, vest unconditional title or other property interests acquired under this project regardless of the fair market value of the property at the end of the award period.

C. Reporting

i. Reporting Requirements

Reporting requirements are identified on the Federal Assistance Reporting Checklist and Instructions, DOE F 4600.2, attached to the award agreement. A sample checklist is available at: https://www.netl.doe.gov/sites/default/files/netl-file/4600.2-FE.pdf.

ii. Subaward and Executive Reporting

Prime Recipients awarded a new Federal financial assistance award greater than or equal to $30,000 as of October 1, 2010 are subject to Federal Funding and Transparency Act of 2006 (FFATA) sub-award reporting requirements as outlined in 2 CFR Chapter 1, Part 170 REPORTING SUB-AWARD AND EXECUTIVE COMPENSATION INFORMATION.

The FFATA Subaward Reporting System (FSRS) is the reporting tool Federal prime awardees (i.e. prime contractors and prime grants recipients) use to capture and report subaward and executive compensation data regarding their first-tier subawards to meet the FFATA reporting requirements. Prime awardees must register with the new FSRS database and report the required data on their first tier subawardees/subrecipient at https://www.fsrs.gov.

Prime awardees must report the executive compensation for their own executives as part of their registration profile in the System for Award Management (SAM). The sub-award information entered in FSRS will then be displayed on https://www.usaspending.gov/ associated with the prime award furthering Federal spending transparency.

Applicants must ensure they have the necessary processes and systems in place to comply with the reporting requirements should they receive funding.

D. Applicant Representations and Certifications

i. Lobbying Restrictions

By accepting funds under this award, the Prime Recipient agrees that none of the funds obligated on the award shall be expended, directly or indirectly, to influence Congressional action on any legislation or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. §1913. This restriction is in addition to those prescribed elsewhere in statute and regulation.

ii. Nondisclosure and Confidentiality Agreements Representations

In submitting an application in response to this FOA the applicant represents that:

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

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

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

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

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

iii. Corporate Felony Convictions and Tax Liabilities Representations (March 2014)

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

(1) It is **not** a corporation that has been convicted of a felony criminal violation under any Federal law within the preceding 24 months; and

(2) It is **not** a corporation that has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

For purposes of these representations the following definition applies:

A Corporation includes any entity that has filed articles of incorporation in any of the 50 states, the District of Columbia, or the various territories of the United States [but not foreign corporations]. It includes both for-profit and non-profit organizations.

VII. Questions/Agency Contacts

A. Questions

Questions regarding the **content of the funding opportunity announcement** must be submitted through the FedConnect portal. You must register with FedConnect to respond as an interested party to submit questions, and to view responses to

questions. It is recommended that you register as soon after release of the FOA as possible to have the benefit of all responses. Applicants are encouraged to review previously issued Questions and Answers prior to the submission of questions. DOE/NNSA will try to respond to a question within 3 business days, unless a similar question and answer have already been posted on the website.

Questions and comments concerning this FOA shall be submitted not later than **3** business days prior to the application due date. Questions submitted after that date may not allow the Government sufficient time to respond.

Questions relating to the **registration process, system requirements, how an application form works**, or the submittal process must be directed to Grants.gov at 1-800-518-4726 or support@grants.gov. DOE/NNSA cannot answer these questions.

B. Agency Contact

Name:	Jennifer Burbage
E-mail:	FOA2614RD6@netl.doe.gov

VIII. Other Information

A. Modifications

Notices of any modifications to this FOA will be posted on Grants.gov and the FedConnect portal. You can receive an email when a modification or an announcement message is posted by registering with FedConnect as an interested party for this FOA. It is recommended that you register as soon after release of the FOA as possible to ensure you receive timely notice of any modifications or other announcements.

B. Government Right to Reject or Negotiate

DOE reserves the right, without qualification, to reject any or all applications received in response to this FOA and to select any application, in whole or in part, as a basis for negotiation and/or award.

C. Commitment of Public Funds

The Contracting Officer is the only individual who can make awards or commit the Government to the expenditure of public funds. A commitment by anyone other than the Contracting Officer, either express or implied, is invalid.

Funding for all awards and future budget periods are contingent upon the availability of funds appropriated by Congress for the purpose of this program and the availability of future-year budget authority.

D. Treatment of Application Information

Applicants should not include trade secret or business sensitive, proprietary, or otherwise confidential information in their application unless such information is necessary to convey an understanding of the proposed project or to comply with a requirement in the FOA. Applicants are advised to not include any critically sensitive proprietary detail.

The Freedom of Information Act, 5 U.S.C. 552, requires DOE to release certain Federal financial assistance documents and records requested by members of the public regardless of the intended use of the information. DOE will release funded applications and funded progress reports, including award data, as legally releasable at the conclusion of the competitive funding process. However, DOE will generally withhold this information during the pendency of competitive stages of the funding process.

If an application includes trade secret or business sensitive, proprietary, or otherwise confidential information, it is furnished to the Federal Government in confidence with the understanding that the information shall be used or disclosed only for evaluation of the application. Such information will be withheld from public disclosure to the extent permitted by law, including the Freedom of Information Act. Without assuming any liability for inadvertent disclosure, DOE will seek to limit disclosure of such information to its employees and to outside reviewers when necessary for merit review of the application or as otherwise authorized by law. This restriction does not limit the Government's right to use the information if it is obtained from another source.

If an applicant chooses to submit business sensitive, trade secrets, proprietary, or otherwise confidential information, the applicant must provide **two copies** of any document of the submission (e.g., Concept Paper, Full Application) that contains such information. The first copy should be marked "non-confidential" with the information believed to be confidential deleted. The second copy should be marked "confidential" and must clearly and conspicuously identify the business sensitive, trade secrets, proprietary, or otherwise confidential information and must 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 Government is not liable for the disclosure or use of unmarked information and may use or disclose such information for any purpose as authorized by law.

The cover sheet of the full application, and other applicant submission must be marked as follows and identify the specific pages business sensitive, trade secrets, proprietary, or otherwise confidential information:

> **Notice of Restriction on Disclosure and Use of Data**:
> Pages [**list applicable pages**] of this document may contain business sensitive, trade secrets, proprietary, or otherwise confidential 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 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. [End of Notice]

In addition, (1) the header and footer of every page that contains business sensitive, trade secrets, proprietary, or otherwise confidential information must be marked as follows: "Contains Trade Secrets, Business Sensitive, Proprietary, Otherwise Confidential Information Exempt from Public Disclosure," and (2) every line or paragraph containing such information must be clearly marked with double brackets or highlighting. DOE will make its own determination about the confidential status of the information and treat it according to its determination.

E. Evaluation and Administration by Non-Federal Personnel

In conducting the merit review, the Government may seek the advice of qualified non-federal personnel as reviewers. The Government may also use non-federal personnel to conduct routine, nondiscretionary administrative activities. The applicant, by submitting its application, consents to the use of non-federal reviewers/administrators. Non-federal reviewers must sign conflict of interest (COI) and non-disclosure agreements (NDA) prior to reviewing an application. Non-federal personnel conducting administrative activities must sign an NDA.

F. Intellectual Property Developed Under This Program (September 2021)

Patent Rights: The government will have certain statutory rights in an invention that is conceived or first actually reduced to practice under a DOE award. 42 U.S.C. 5908 provides that title to such inventions vests in the United States, except where 35 U.S.C. 202 provides otherwise for nonprofit organizations or small business firms. However, the Secretary of Energy may waive all or any part of the rights of the United States subject to certain conditions.

Class Patent Waiver: Pursuant to 10 CFR Part 784, the DOE has issued a class patent waiver that applies to this FOA. Under this class waiver, any domestic entity other than a domestic small business firm or domestic nonprofit organization may elect title to their subject inventions similar to the right provided to domestic small business firms and domestic nonprofit organization by law (see below). In order to avail itself of the class waiver, such domestic entity must agree, among other things, that any products embodying or produced through the use of a subject invention (first created or reduced to practice under this program) will be substantially manufactured in the United States, unless DOE agrees otherwise.

Right to Request Patent Waiver: A selected entity may request a waiver of all or any part of the rights of the United States in inventions conceived or first actually reduced to practice in performance of an agreement as a result of this announcement, in advance of or within 30 days after the effective date of the award. Even if such advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver of the rights of the United States in identified inventions, i.e., individual inventions conceived or first actually reduced to practice in performance of the award. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784 see https://www.energy.gov/gc/services/technology-transfer-and-procurement/office-assistant-general-counsel-technology-transf-1 for further information.

Domestic small businesses and domestic nonprofit organizations: Domestic small businesses and domestic nonprofit organizations will receive the patent rights clause at 37 CFR 401.14, i.e., the implementation of the Bayh-Dole Act. This clause permits domestic small business and domestic nonprofit organizations to retain title to subject inventions. Therefore, small businesses and nonprofit organizations do not need to request a patent waiver.

- 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 shall include the U.S. Competitiveness Provision in accordance with Section IV, "Application and Submission Information; U.S. Competitiveness" of this FOA. A copy of the DEC can be found at https://www.energy.gov/gc/determination-exceptional-circumstances-decs.
- Pursuant to 37 CFR § 401.4, any nonprofit organization or small business firm as defined by 35 U.S.C. 201 affected by any 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.

- DOE may issue and publish on the website above further DECs prior to the issuance of awards under this FOA. DOE may require additional submissions or requirements as authorized by any applicable DEC.

G. Government Rights in Subject Inventions

Where prime recipients, subrecipients, and contractors retain title to subject inventions, the United States government retains certain rights.

Government Use License

The United States 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 government contractors.

March-In Rights

The United States 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 to a third party. In addition, the government may grant licenses for use of the subject invention when a prime recipient, subrecipient, or their assignees and exclusive licensees refuse to do so.

DOE may exercise its march-in rights only 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 satisfied manner;
- The owner has not met public use requirements specified by federal statutes in a reasonably satisfied manner; or
- The United States manufacturing requirement has not been met.

Any determination that march-in rights are warranted must follow a fact-finding process in which the recipient has certain rights to present evidence and witnesses, confront witnesses and appear with counsel and appeal any adverse decision. To date, DOE has never exercised its march-in rights to any subject inventions.

H. 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.

"Limited Rights Data": The United States government will not normally require delivery of confidential or trade secret-type 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.

Government Rights in Technical Data Produced Under Awards: The United States government normally retains unlimited 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 DOE awards under this FOA may be protected from public disclosure for up to five years after the data is generated ("Protected Data"). For awards permitting Protected Data, the protected data must be marked as set forth in the awards intellectual property terms and conditions and a listing of unlimited rights data (i.e., non-protected data) must be inserted into the data clause 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.

I. Copyright

The prime recipient and subrecipient(s) may assert copyright in copyrightable works, such as software, first produced under the award without DOE approval. When copyright is asserted, the government retains a paid-up nonexclusive, irrevocable worldwide license to reproduce, prepare derivative works, distribute copies to the public, and to perform publicly and display publicly the copyrighted work. This license extends to contractors and others doing work on behalf of the government.

J. Energy Data eXchange (EDX) Requirements (December 2022)

The DOE is required to improve access to federally funded research results, proper archiving of digital data, and expanded discovery and reuse of research datasets per DOE and Executive Orders. The Energy Data eXchange (EDX) is a data laboratory developed and maintained by NETL to find, connect, curate, use, and re-use data to advance fossil energy and environmental research and development (R&D).

Data products generated under the resulting award will be required to be submitted in the EDX at https://edx.netl.doe.gov/. Data products include but are not limited to

software code, tools, applications, webpages, portfolios, images, videos, and datasets.

EDX uses federation and web services to elevate visibility for publicly approved assets in the system, including connections with DOE's Office of Scientific and Technical Information (OSTI) systems, Data.gov, and Re3Data. This ensures compliance with federal requirements, while raising visibility for researcher's published data products to promote discoverability and reuse.

EDX supports a wide variety of file types and formats including: 1) data, 2) metadata, 3) software/tools, and 4) articles (provided that there is an accompanying Government use license). A partial list of file formats accepted by EDX is provided below, however, EDX is designed for flexibility and accepts all types of file formats.

- Common Data Product Submission Formats: ASC, AmiraMesh, AVI, CAD, CSV, DAT, DBF, DOC, DSV, DWG, GIF, HDF, HTML, JPEG2000, JPG, MOV, MPEG4, MSH/CAS/DAT, NetCDF, PDF, PNG, PostScript, PPT, RTF, Surface, TAB, TIFF, TIFF Stacks, TXT, XLS, SML, Xradio, ZIP, and others.
- Geographic Formats: APR, DBF, DEM, DLG, DRG, DXF, E00, ECW, GDB, GeoPDF, GeoTIFF, GML, GPX, GRID, IMG, KML, KMZ, MOB, MrSID, SHP, and others.

Information provided to EDX will be made publicly available, unless authorized under the resulting award. Additional information on EDX is available at https://edx.netl.doe.gov/about.

When data products are submitted to EDX, the data product will need to be registered with a digital object identifier (DOI) through OSTI to ensure more visibility in other search repositories (i.e., osti.gov, data.gov, Google Scholar, etc.). The OSTI DOI can be established through an application programming interface (API) by completing just a few additional fields.

The Recipient or subrecipient should coordinate with the Project Manager on an annual basis to assess if there is data that should be submitted to EDX and identify the proper file formats prior to submission. All final data products shall be submitted to EDX by the Recipient prior to the completion of the project.

K. Notice Regarding Eligible/Ineligible Activities

Eligible activities under this program include those which describe and promote the understanding of scientific and technical aspects of specific energy technologies, but not those which encourage or support political activities such as the collection and dissemination of information related to potential, planned or pending legislation.

L. Notice of Right to Conduct a Review of Financial Capability

DOE reserves the right to conduct an independent third-party review of financial capability for applicants that are selected for negotiation of award (including personal credit information of principal(s) of a small business if there is insufficient information to determine financial capability of the organization).

M. Notice of Potential Disclosure Under Freedom of Information Act (FOIA)

Applicants should be advised that identifying information regarding all applicants, including applicant names and/or points of contact, may be subject to public disclosure under the Freedom of Information Act, whether or not such applicants are selected for negotiation of award.

N. Requirement for Full and Complete Disclosure

Applicants are required to make a full and complete disclosure of all information requested. Any failure to make a full and complete disclosure of the requested information may result in:

- 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.

O. Retention of Submissions

DOE expects to retain copies of all submissions. No submissions will be returned. By applying to DOE for funding, applicants consent to DOE's retention of their submissions.

P. Protected Personally Identifiable Information

In responding to this FOA, applicants must ensure that Protected Personally Identifiable Information (PII) is not included in the application documents. These documents will be used by the Merit Review Committee in the review process to evaluate each application. PII is defined by the Office of Management and Budget (OMB) as:

Any information about an individual maintained by an agency, including but not limited to, education, financial transactions, medical history, and criminal or employment history and information that can be used to distinguish or trace an individual's identity, such as their name, social security number, date and place of birth, mother's maiden name, biometric records, etc., including any other personal information that is linked or linkable to an individual.

This definition of PII can be further defined as: (1) Public PII and (2) Protected PII.

1. Public PII: PII found in public sources such as telephone books, public websites, business cards, university listing, etc. Public PII includes first and last name, address, work telephone number, email address, home telephone number, and general education credentials.

2. Protected PII: PII that requires enhanced protection. This information includes 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 the application files listed above to be evaluated by the Merit Review Committee. This list is not all inclusive.

- 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
- Employment history and other employment information 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
- Security clearance history or related information (not including actual clearances held)

Q. Annual Compliance Audits

If an institution of higher education, non-profit organization, or state/local government is a Prime Recipient or Subrecipient and has expended $750,000 or more of Federal funds during the non-Federal entity's fiscal year, then a single or program-specific audit is required. For additional information, please refer to 2 C.F.R. § 200.501 and Subpart F.

If a for-profit entity is a Prime Recipient and has expended $750,000 or more of DOE funds during the entity's fiscal year, an annual compliance audit performed by an independent auditor is required. For additional information, please refer to 2 C.F.R. § 910.501 and Subpart F.

Applicants and subrecipients (if applicable) should propose sufficient costs in the project budget to cover the costs associated with the audit. DOE will share in the cost of the audit at its applicable cost share ratio.

R. Accounting System

If your application is selected for negotiation toward award, you should have an accounting system that meets government standards for recording and collecting costs. Reference 2 CFR 200 Subpart D for the applicable standards. If you have not had prior government awards or a recent accounting system review, DOE may request that the Defense Contract Audit Agency (DCAA) or an independent auditor verify that the accounting system is acceptable. A resulting award may contain a Term and Condition that prohibits DOE reimbursement until the system is deemed acceptable.

S. Indirect Rates

Potential recipients and major subrecipients will need to demonstrate how indirect rates are developed using an acceptable government methodology or current rate agreement. The Prime Recipient and major subrecipients may be subject to a DCAA or independent auditor indirect rate review if there has not been a certified rate audit within the previous twelve months. Additionally, annual indirect cost reconciliations are required, as applicable.

T. Prohibition on Certain Telecommunications and Video Surveillance Services or Equipment

As set forth in 2 CFR 200.216, recipients and subrecipients are prohibited from obligating or expending project funds (federal and recipient cost share) to procure or obtain; extend or renew a contract to procure or obtain; exercise an option to procure, or enter into a contract (or extend or renew a contract) to procure or obtain equipment, services, or systems that uses covered telecommunications equipment or services as a substantial or essential component of any system, or as critical technology as part of any system. As described in Public Law 115-232, section 889, covered telecommunications equipment is telecommunications equipment produced by Huawei Technologies Company or ZTE Corporation (or any subsidiary or affiliate of such entities).

See Public Law 115-232, Section 889, 2 CFR 200.216, and 2 CFR 200.471 for additional information.

U. Prohibition Related to Foreign Government-Sponsored Talent Recruitment Programs (April 2023)

i. **Prohibition**

Persons participating in a Foreign Government-Sponsored Talent Recruitment Program of a Foreign Country of Risk are prohibited from participating in projects selected for Federal funding under this FOA. Should an award result from this FOA, the recipient must exercise ongoing due diligence to reasonably ensure that no individuals participating on the DOE-funded project are participating in a Foreign Government-Sponsored Talent Recruitment Program of a Foreign Country of Risk. Consequences for violations of this prohibition will be determined according to applicable law, regulations, and policy. Further, the recipient must notify DOE within five (5) business days upon learning that an individual on the project team is or is believed to be participating in a foreign government talent recruitment program of a foreign country of risk. DOE may modify and add requirements related to this prohibition to the extent required by law.

ii. Definitions

1) **Foreign Government-Sponsored Talent Recruitment Program**. An effort directly or indirectly organized, managed, or funded by a foreign government, or a foreign government instrumentality or entity, to recruit science and technology professionals or students (regardless of citizenship or

national origin, or whether having a full-time or part-time position). Some foreign government-sponsored talent recruitment programs operate with the intent to import or otherwise acquire from abroad, sometimes through illicit means, proprietary technology or software, unpublished data and methods, and intellectual property to further the military modernization goals and/or economic goals of a foreign government. Many, but not all, programs aim to incentivize the targeted individual to relocate physically to the foreign state for the above purpose. Some programs allow for or encourage continued employment at U.S. research facilities or receipt of Federal research funds while concurrently working at and/or receiving compensation from a foreign institution, and some direct participants not to disclose their participation to U.S. entities. Compensation could take many forms including cash, research funding, complimentary foreign travel, honorific titles, career advancement opportunities, promised future compensation, or other types of remuneration or consideration, including in-kind compensation.

2) **Foreign Country of Risk**. DOE has designated the following countries as foreign countries of risk: Iran, North Korea, Russia, and China. This list is subject to change.

V. Implementation of Executive Order 13798, Promoting Free Speech and Religious Liberty (November 2020)

States, local governments, or other public entities may not condition sub-awards in a manner that would discriminate, or disadvantage subrecipients based on their religious character.

W. Affirmative Action and Pay Transparency Requirements

All applicants must comply with all applicable federal labor and employment laws, including but not limited to Title VII of the Civil Rights Act of 1964, the Fair Labor Standards Act, the Occupational Safety and Health Act, and the National Labor Relations Act, which protects employees' right to bargain collectively and engage in concerted activities for the purpose of workers' mutual aid or protection.

All federally assisted construction contracts exceeding $10,000 annually will be subject to the requirements of Executive Order 11246, Equal Employment Opportunity:

(1) Recipients, subrecipients, contractors, and subcontractors are prohibited from discriminating in employment decisions on the basis of race, color, religion, sex, sexual orientation, gender identity, or national origin.

(2) Recipients and contractors are required to take affirmative action to ensure that equal opportunity is provided in all aspects of their employment. This includes flowing down the appropriate language to all subrecipients, contractors, and subcontractors.

(3) Recipients, subrecipients, contractors, and subcontractors are prohibited from taking adverse employment actions against applicants and employees for asking about, discussing, or sharing information about their pay or, under certain circumstances, the pay of their co-workers.

The Department of Labor's (DOL) Office of Federal Contractor Compliance Programs (OFCCP) uses a neutral process to schedule compliance evaluations. Consult OFCCP's Technical Assistance Guide[7] to gain an understanding of the requirements and possible actions the recipients, subrecipients, contractors, and subcontractors must take. Additional guidance may also be found in the National Policy Assurances, produced by DOE.

X. Foreign Collaboration Considerations

a. Consideration of new collaborations with foreign entities, organizations, and governments. The recipient will be required to provide DOE with advanced written notification of any potential collaboration with foreign entities, organizations, or governments in connection with its DOE-funded award scope. The recipient will then be required to await further guidance from DOE prior to contacting the proposed foreign entity, organization, or government regarding the potential collaboration or negotiating the terms of any potential agreement.

b. Existing collaborations with foreign entities, organizations, and governments. The recipient will be required to provide DOE with a written list of all existing foreign collaborations in which has entered in connection with its DOE-funded award scope.

c. Description of collaborations that should be reported. In general, a collaboration will involve some provision of a thing of value to, or from, the recipient. A thing of value includes but may not be limited to all resources made available to, or from, the recipient in support of and/or related to the DOE award, regardless of whether or not they have monetary value. Things

[7] See OFCCP's Technical Assistance Guide at: https://www.dol.gov/sites/dolgov/files/ofccp/Construction/files/ConstructionTAG.pdf?msclkid=9e397d68c4b111ec9d8e6fecb6c710ec Also see the National Policy Assurances http://www.nsf.gov/awards/managing/rtc.jsp

of value also may include in-kind contributions (such as office/laboratory space, data, equipment, supplies, employees, students). In-kind contributions not intended for direct use on the DOE award but resulting in provision of a thing of value from or to the DOE award must also be reported. Collaborations do not include routine workshops, conferences, use of the recipient's services and facilities by foreign investigators resulting from its standard published process for evaluating requests for access, or the routine use of foreign facilities by awardee staff in accordance with the recipient's standard policies and procedures.

IX. Appendices

Appendix A – AOI-1 Carbon Conversion Technology

The objective of **AOI-1** is to support R&D investigating the conversion of carbon dioxide (CO_2) into environmentally responsible and economically feasible products. The Carbon Conversion Program will support technologies which utilize CO_2 from point sources such as power/industrial flue gas and direct air capture to yield valued-added products while simultaneously reducing CO_2 emissions. Supported R&D will validate results through rigorous product testing, life cycle analysis, and techno-economic analysis.

Reactive carbon capture (RCC) presents a transformational process intensification approach to carbon capture and conversion by combining both processes to drive down cost and improve process efficiency. The conventional approach to carbon capture is to first separate carbon CO_2 from flue gas (point source capture) or the atmosphere and then, as applicable, to regenerate the capture medium and to compress, transport, and store or otherwise utilize the purified CO_2 in other applications. The act of capturing CO_2 in this method is often accompanied downstream by energy intensive and costly support infrastructure and processes to purify, compress, transport and/or store the captured CO_2, and to regenerate the capture medium.

In a RCC approach, the captured CO_2 is directly converted to long-lived products without going through a purified CO_2 intermediate.[8,9] This eliminates the need to regenerate the capture medium and the need to purify, compress, transport, or store the captured CO_2, thus potentially reducing capital and operating expenditures and energy requirements. The process intensification realized through RCC solutions is of interest to DOE's Carbon Conversion, Carbon Dioxide Removal, and Point Source Carbon Capture Programs.

Applications are being sought for the following subtopics:

AOI-1F. ***Reactive Carbon Capture Approaches for Point Source Capture or Atmospheric Capture with Integrated Conversion to Useful Products***

Research Sought

The objective of AOI-1F is to perform conceptual design studies followed by a bench scale validation of reactive carbon capture (RCC) approaches utilizing CO2 from exhaust flue gas streams at electric generation and industrial facilities, or from the atmosphere (E.g., direct air capture, enhanced mineralization, biomass carbon removal, marine CDR). There are three

[8] T. Deutsch, S. Baker, P. Agbo, D. R. Kauffman, J. Vickers, J. Schaidle. Summary Report of the Reactive CO2 Capture: Process Integration for the New Carbon Economy Workshop. (2020).

[9] Freyman et al. Reactive CO2 capture: A path forward for process integration in carbon management. Joule. (2023).

subtopic areas for this AOI:

1F-a: Catalytic RCC Approaches (e.g., thermal, electrochemical, plasma)
1F-b: Biological RCC Approaches
1F-c: Mineralization RCC Approaches

In the Project Title, Applicants must clearly specify the: (1) subtopic area (i.e., 1F-a, 1F-b, or 1F-c) and (2) proposed CO_2 source (i.e., exhaust flue gas streams or the atmosphere).

Applicants must submit a preliminary screening-level, greenhouse gas (GHG) only LCA with their Phase 1 application. The preliminary LCA must demonstrate carbon neutral production of the proposed long-lived product(s), at a minimum, to be considered an eligible atmospheric RCC solution.

Applicants must also submit a preliminary techno-economic analysis (TEA) with their Phase 1 application. The preliminary TEA must show a potential improvement in the cost and efficiency of carbon capture and conversion via RCC versus a reference conventional process with sequential capture and conversion.

The proposed project will test the technology in an integrated, continuous bench scale system under conditions that will closely simulate real CO_2 gas streams, including realistic CO_2 concentrations, impurities, and space velocities. Any individual component of the integrated RCC system must have already achieved a TRL of 3 in advance of application submission under this FOA. Final TEA must demonstrate significant progress towards a 30% reduction in the product cost and 30% improvement in energy efficiency of carbon capture and conversion via RCC versus a reference conventional process with sequential capture and conversion Final LCA must demonstrate either carbon neutral production for atmospheric RCC, or progress toward carbon neutral production for RCC utilizing CO_2 from exhaust flue gas streams.

Of particular interest are:

- RCC approaches integrated with industrial facilities. The industrial sectors of interest include but are not limited to: (i) chemical production (e.g., petrochemicals, hydrogen) excluding ethanol, (ii) mineral production (e.g., cement and lime), (iii) pulp and paper production, (iv) iron and steel production, (v) glass production, and (vi) oil refining;
- RCC approaches for carbon management applications where CO2 storage options are not readily available, including space constrained systems (e.g., commercial buildings, hard to decarbonize mobile sources);
- RCC approaches integrating CO2 conversion processes with pre-combustion carbon capture systems;
- RCC approaches that are maximizing the one-pass CO2 capture efficiency;
- RCC approaches integrated with atmospheric CO2 capture, including direct air capture, enhanced mineralization, biomass carbon removal, and marine CDR;
- RCC approaches with ability to utilize transformational carbon capture materials, catalysts, and novel concepts or hybrid systems;

- RCC approaches with ability to reduce auxiliary power by utilizing novel equipment, component designs, and/or process schemes that allow heat integration; and
- RCC approaches that are scalable and aligned with product markets.

AOI-1F will be carried out in two phases with a competitive down-select between Phases 1 and 2, as shown in **Figure 1**. The two phases are: Phase 1 – *Conceptual Design and Feasibility*, and Phase 2 – *Integrated System Bench-scale Validation* and their schedule is shown in **Table 1.**

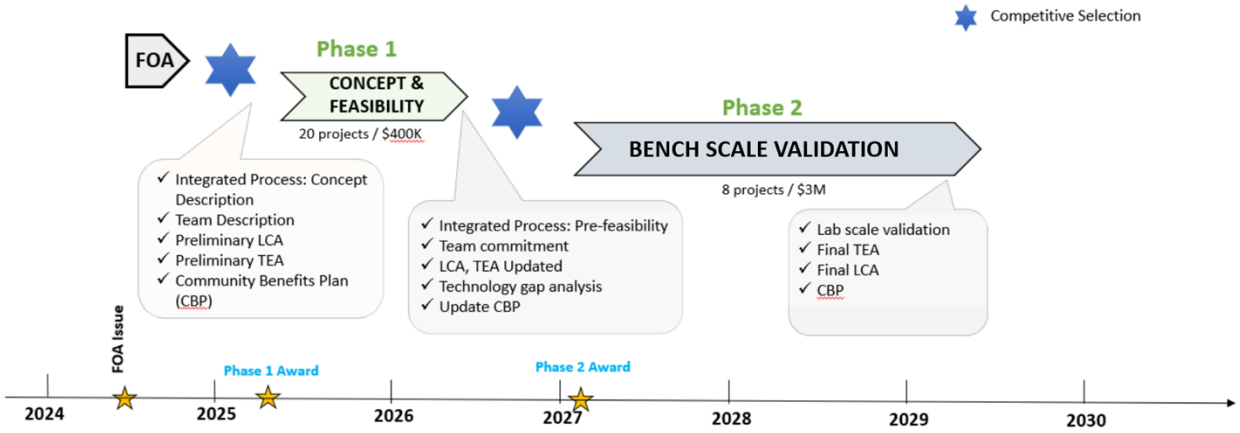


Figure 1. AOI-1F Notional Conceptual Timeline

Table 1. AOI-1F Schedule

Phase 1* Conceptual Design and Feasibility	**Administrative Review Period**	**Phase 2** Lab Scale Validation
12 months	9 months	30 months

***Phase 1** will include: (1) a technical period of performance of 12 months and (2) an administrative period of 9 months for DOE to execute the Phase 2 competitive down selection process.

While only detailed Phase 1 applications will be solicited under **AOI-1F**, information relating to initial plans to carry out Phase 2 will be required to assess the potential viability of the overall RCC validation project. The comprehensive list of application requirements for Phase 2, including Merit Review Criteria that will be used to evaluate the application for Phase 2, will be contained in Phase 1 awards.

Phase 1 – Conceptual Design and Feasibility

For AOI-1F, Phase 1 selected projects will perform activities including, but not limited to, those

listed below:
1. Project Scope that includes research objectives and the summary of the proposed project (i.e., Phase 1 and Phase 2).
2. Conceptual design of the integrated Bench Scale RCC System to be fabricated and operated in Phase 2. The conceptual design shall include, at a minimum: description of component technologies including state point data tables; high-level process flow diagrams; heat and material balances prepared based on process modeling and/or experimental evaluations; and quantity of product generated. Phase 1 Recipients may conduct experimental work, up to 20% of the proposed Phase 1 scope, that directly supports the conceptual design of the integrated RCC process.
3. State Point Data Table. Phase 1 Recipients must submit updated State Point Data Table(s) for the selected material composition(s) for each RCC process component (e.g., catalyst, reactor, separation process, etc.). Details regarding the type of information to be included in the State Point Data Table will be provided in **Appendix S**.
4. Preliminary Techno-economic Analysis (TEA). Phase 1 Recipients must submit a preliminary TEA that covers a reference RCC plant that captures at least 100,000 tonnes CO_2/year in accordance with **Appendix O(a)**.
5. Preliminary Life Cycle Analysis (LCA). Phase 1 Recipients must submit an initial LCA in accordance with **Appendix P(a)**.
6. Technology Maturation Plan (TMP). Phase 1 Recipients must submit a TMP in the format provided in **Appendix K** that describes the current technology readiness level (TRL) of the proposed technology/technologies, relates the proposed project work to maturation of the proposed technology, describes the expected TRL at the end of the project, and describes any known post-project research and development necessary to further mature the technology.
7. Initial Environmental Health and Safety (EH&S) Analysis. Phase 1 Recipients must submit an initial EH&S analysis of the proposed technology in accordance with the format provided in **Appendix Q**. EH&S analysis should include discussion regarding air and water emissions and co-benefits, water utilization, solid waste streams, noise, and potential environmental impacts of the technology, including toxicological effects and hazards of emissions and waste streams.
8. Technology Gap Analysis. Phase 1 Recipients must submit a Technology Gap Analysis (TGA) in the format provided in **Appendix N** to identify critical components that need to be developed during Phase 2 of the proposed project.
9. R&D Community Benefits Plan (CBP). As a final deliverable, Phase 1 Recipients must report on R&D CBP accomplishments.

Note that only Phase 1 Recipients that have successfully completed all Phase 1 activities and requirements will be afforded the opportunity to submit a renewal application for Phase 2 for consideration under the competitive, down-selection process.

AOI-1F Phase 2 – Integrated Bench Scale System Validation

The objectives of Phase 2 will be to complete the detailed design, fabrication, and operation of the proposed RCC bench scalesystem. For the competitive down-select, Phase 2 applications are anticipated to contain the following sections:

- Phase 1 Topical Report detailing the results of Phase 1;
- Phase 2 Budget Justification;
- Phase 2 Technical Narrative (including updated Phases 2 Statement of Project Objectives, or SOPO); and
- Phase 2 Project Management Plan.

The comprehensive list of application requirements for Phase 2, including Merit Review Criteria that will be used to evaluate the application for Phase 2, will be contained in Phase 1 awards.

Technical Elements that Must be Included in Phase 1 Applications

1. **Description of the RCC process**, including but not limited to:
   i. Chemistry and/or separation mechanisms, including kinetics and thermodynamics;
   ii. Current state of the individual materials or processes that will be the focus of the proposed project;
   iii. Process operating conditions;
   iv. CO_2 concentration(s) of the inlet gas to be tested; and
   v. End-use application for the product.
2. **Preliminary Conceptual Design** of the integrated RCC process to be fabricated and operated in Phase 2. The preliminary conceptual design shall include, at a minimum: description of each individual technology including state point data tables; high-level process flow diagrams; heat and material balances; and quantity of product generated. The potential commercial application of the RCC system and how the RCC system will be integrated with that application should be outlined. If applicable, Phase 1 Applicants should discuss the purpose for, and plans to conduct, experimental work required to optimize the conceptual design of the integrated RCC process. Anticipated benefits of the work as it relates to the conceptual design should be discussed in detail.

3. Technology Competitive Assessment. A thorough competitive assessment on how the proposed integrated process would lead to performance advancements relative to the currently available reactive carbon capture processes is required. Anticipated benefits, as well as challenges for the technology should also be discussed in detail.

4. Risk Assessment Analysis. Of particular importance is identification of major technical risks and a discussion on how the proposed project will mitigate those risks.

5. Preliminary State Point Data Table. Submission of preliminary State Point Data Table(s) for the proposed material composition(s) for each RCC process component (e.g., catalyst, reactor, separation process, etc.) is required. Details regarding the type of information to be included in the State Point Data Table will be provided in **Appendix S**. It is expected that the applicants have already identified a material candidate for the RCC process and have previously performed necessary laboratory measurements and data collection supporting the efficacy of their proposed materials. The proposed compositions performance should be substantiated by providing experimental evidence measured at the lab scale, under relevant conditions. The applicant must

provide data and theory supporting the efficacy of the functional material, as well as for the other materials or elements included in this effort.

6. Summary of a Preliminary Techno-Economic Analysis (TEA) and Preliminary Life Cycle Analysis (LCA). Applicants are required to submit summary results of a preliminary screening-level, greenhouse gas (GHG) only LCA and a preliminary TEA covering both the RCC system and balance-of-plant for a reference plant that captures at least net 100,000 tonnes CO_2/year based on LCA. The summary results should provide information for all process components from prior conducted analysis, including: (i) mass and energy balances, (ii) estimates of heating and cooling duties and electric power requirements covering the system and balance-of-plant, (iii) the estimated cost of the reactive carbon capture system, (iv) the estimated land and water usage, as well as (vi) the cost of product on a $/tonne basis. Preliminary TEA included in the application should be prepared based upon prior engineering design and costing work and must show a potential improvement in the cost and efficiency of carbon capture and conversion via RCC versus a reference conventional process with sequential capture and conversion. Preliminary TEA does not necessarily have to conform to the requirements in **Appendix O(a)**.

Applicants are required to submit the results of a preliminary screening-level, GHG only LCA. This screening LCA only needs to include energy inputs, covering the production process for a reference plant. The preliminary LCA must demonstrate carbon neutral production of the proposed long-lived product(s), at a minimum, to be considered an eligible atmospheric RCC solution. Preliminary screening-level, GHG only LCA does not necessarily have to conform to the requirements in **Appendix P(a)**.

7. R&D Community Benefits Plan (CBP). Applicants must submit a plan that includes all elements discussed in Appendix L in a template provided in Appendix M.

Research Scope and Attributes that are Not of Interest

Areas considered to be outside the scope of **AOI-1F** are specified in Section I.D. Applications that propose work in these areas will be considered nonresponsive and will not be evaluated.

Anticipated Technology Readiness Level

Beginning of project: 3

- TRL 3: Analytical and experimental critical function and/or characteristic proof of concept.

End of project: 4

- TRL 4: System validation in a laboratory environment.

Success Metric(s)

Successful projects will complete a minimum two-month bench scale validation of the optimized integrated RCC process using CO_2 from a simulated point source or air. The final TEA must demonstrate significant progress towards a 30% reduction in the product cost and 30% improvement in energy efficiency of carbon capture and conversion via RCC versus a reference conventional process with sequential capture and conversion and final LCA must demonstrate either carbon neutral production for atmospheric RCC, or progress toward carbon neutral production for RCC

utilizing CO_2 from exhaust flue gas streams. Quantitative success metric targets will be established during negotiations with successful applicants.

Appendix B – RESERVED

Appendix B (AOI-2 – Carbon Dioxide Removal Technology) is hereby held in reserve for future FOA openings. Applications are NOT currently being accepted in AOI-2 in this sixth FOA opening.

Appendix C – AOI-3 Point Source Carbon Capture Technology

As noted in the Office of Fossil Energy and Carbon Management Strategic Vision[10], reduced capture cost has long been acknowledged as a critical component to spur the deployment of carbon capture for power generation and low-CO_2-concentration industrial sources. Since DOE R&D efforts for carbon capture began in the early 2000s, cost estimates have fallen by 60 percent through the implementation of energy and process efficiencies and the development of advanced capture media (e.g., solvents, sorbents and membranes). These developments have led to a reduction in both capital and operating costs. Additionally, ongoing efforts to develop transformational technologies have identified and are targeting opportunities for further cost reductions.

The objective of **AOI-3** is to solicit applications that are specifically focused on developing lower cost, highly-efficient technologies for point source carbon capture from fossil fuel power plants and industrial point sources capturing CO_2 that is suitable for secure geologic carbon storage, including in situ mineralization or CO_2 conversion into long-lasting products (e.g., synthetic aggregates, concrete, durable carbon products).

Applications are being sought for the following subtopics:

Engineering-Scale Testing AOIs

AOI-3F. ***Engineering-Scale Testing of Transformational Carbon Capture Technologies for Natural Gas Power Plants (NGPP)***

For **AOI-3F**, applications are sought to design, build and test *transformational* carbon capture systems capable of validating 95% or greater carbon capture efficiency while producing CO_2 with 95% or greater purity from flue gas conditions indicative of a *natural gas combined cycle* power plant. Engineering-scale **portable** systems proposed for **AOI-3F are highly encouraged** and must be designed such that they can be moved to other host site locations for additional testing on alternative flue gas sources. These portable systems developed under **AOI-3F** could be utilized on industrial gas sources in future projects. NGPPs are defined as natural gas combined cycle (NGCC), NGCC with combined heat and power (NGCC-CHP) and natural gas simple cycle (NGSC).

AOI-3G. ***Engineering-Scale Testing of Transformational Carbon Capture Technologies in Portable Systems at Industrial Plants***

[10] 2022-Strategic-Vision-The-Role-of-Fossil-Energy-and-Carbon-Management-in-Achieving-Net-Zero-Greenhouse-Gas-Emissions.pdf

For **AOI-3G**, applications are sought to design and build *portable carbon capture systems to test transformational* carbon capture technologies. Systems should validate 95% or greater carbon capture efficiency and produce CO_2 with 95% or greater purity from *industrial process emissions* under real flue gas conditions at a domestic industrial facility. Portable engineering-scale systems are required for **AOI-3G** due to the variety of industrial sources that have different process/flue gas compositions and therefore require testing at multiple locations and from a variety of sources. The industrial sectors of interest include but are not limited to: (i) chemical production (e.g., petrochemicals, H_2) excluding ethanol and ammonia production, (ii) mineral production (e.g., cement and lime), (iii) pulp and paper production, (iv) iron and steel production, (v) glass production, and (vi) oil refining (e.g., catalytic cracker, hydrocracking).

Research Sought

The successful applicants will test their carbon capture technology, at engineering-scale in an integrated system for at least two-months of continuous operation. All projects must utilize a test site in the United States. Engineering-scale testing is defined as pilot facilities with the capacity to capture CO_2 from a flue/process gas stream of at least 500 lb/hr. For **AOI-3F**, if an applicant proposes an engineering-scale testing unit that cannot be moved to other locations, the minimum acceptable scale is 5 tonnes CO_2/day.

To be considered ready for engineering-scale testing, technologies proposed must have already successfully completed an integrated, continuous, bench scale validation (i.e., total system or multi-component system) with simulated flue gas having a similar CO_2 concentration as a NGPP(**AOI-3F**) or as the industrial application (**AOI-3G**)**.** Applicants are highly encouraged to propose teams that include both of the following:

- Carbon capture technology developer,
- Host site (NGPP for **AOI-3F** or Industrial plant operator for **AOI-3G**).

If an applicant is proposing team member(s), letter(s) of commitment from the member(s) are required as evidence of the participation. The letter(s) of commitment must be signed by the person authorized to commit resources on behalf of the organization. Letter(s) should demonstrate the partner's level of commitment to the project, such as host site access, data access, and/or advisory services, etc.

For AOI-3G, applications proposing the testing of open-source solvents (e.g., MEA or CEASR-1) at industrial sources not previously reported in the literature are of interest only if all design, performance, and environmental data is provided to the public.

Projects selected under **AOI-3F and AOI-3G** will perform activities including, but not limited to, those listed below:

a. Synthesis of required quantities of carbon capture materials (e.g., structured sorbents, solvents, membrane materials), structured materials systems (e.g., monoliths, laminar

structures, electrodes, membrane modules), and other separation materials that cannot be sourced from existing commercial manufacturers to support the engineering-scale experimentation.

b. Qualification of potential scale-up manufacturers for the carbon capture materials and structured material systems.
c. Design, fabrication and commissioning of the engineering-scale system as a *portable unit* (**AOI-3F or AOI-3G**) or stationary unit (**AOI-3F only**).
d. Engineering-scale testing of the carbon capture technology in a continuous engineering-scale system, under normal steady-state and off-load conditions with flue gas indicative of a NGPP (**AOI-3F**) or the selected industrial facility process gas (**AOI-3G**). Testing should also consider high capture rates (greater than 95%) and the performance of the capture system under transient conditions (e.g, cold/hot startup, load following) and how this performance translates/effects the capabilities to achieve annual average carbon capture rate targets.
e. Collection and reporting of mass and energy balance, CO_2 working capacity and state point operating data (e.g., flowrates, compositions, pressures, temperatures) for all significant test unit streams.
f. Bench scale accelerated life testing of the carbon capture material to identify any degradation products formed in the proposed application (i.e., NGPP, industrial process). If applicable, development of analytical methods to quantify the degradation products.
g. Collection of the inlet and outlet criteria pollutants (e.g., NOx, SOx, PM) and capture-technology-related emissions (e.g., solvent/sorbent losses and their degradation by-products) through on-line, continuous measurements for the entire duration of the engineering-scale testing of the carbon capture system.
h. Reporting of carbon capture efficiency, and, as applicable, steam duty, and absorber/desorber secondary emissions in parametric testing as a function of conditions tested (e.g., space velocity, temperature, feed composition).
i. Collection and reporting of data from steady-state tests for *a minimum of two months* to assess long term performance of the carbon capture materials under real exhaust stream conditions.
j. Disposition of carbon capture materials (e.g., solvents, sorbents, membranes) and decommissioning of equipment.
k. Air dispersion modelling of potential emissions associated with the proposed capture media that predict environmental fate and transport of specific species of interest.
l. **Updated Process Model.** Successful applicants will be required to update the carbon capture process model with the data acquired during the engineering scale testing, according to the guidance provided in Appendix U.
m. **Updated State Point Data Table.** Successful Applicants will be required to submit a final *State Point Data Table* 90 days prior to project completion based on the experimental data acquired.
n. **Techno-economic Analysis (TEA).** Successful applicants will be required to prepare a TEA in the format provided in Appendix O(b) of the FOA. The initial TEA is due 120 days after award and should be updated based on the experimental data acquired

throughout the project period of performance. A final TEA should be submitted 90 days prior to project completion.

o. **Environmental Health & Safety (EHS) Analysis.** Successful applicants will be required to prepare an EHS analysis that will be submitted 90 days prior to project completion in the format provided in Appendix Q of the FOA.
p. **Technology Maturation Plan (TMP).** The initial TMP is due 90 days after award in the format provided in Appendix K of the FOA and should be updated as needed throughout the project period of performance. A final TMP should be submitted 90 days prior to project completion of the project.
q. **R&D Community Benefits Plan:** As a final deliverable, Recipients must report on R&D CBP accomplishments.

Technical Elements that Must be Included in Applications

Applicants are expected to include the following *in the* application materials:

1) **Technology Competitive Assessment**. A thorough competitive assessment on how the proposed technology would lead to performance advancements relative to currently available carbon capture processes is required. Anticipated benefits, as well as challenges for the technology should also be discussed in detail.

2) **Carbon Capture Technology Description**. The applicants are required to describe the proposed portable, transformational carbon capture technology including, but not limited to the following:

   a. preliminary process flow diagrams
   b. heat and material balances
   c. steam and power requirements
   d. as applicable, a discussion of the absorption/desorption chemistry and operating cycle for solvent and sorbent systems, and
   e. as applicable, a description of relevant membrane chemistry, including transport mechanism.

3) **Carbon Capture Technology Readiness Level Evaluation**. It is expected that the applicants have already validated their carbon capture technology **at TRL 5** in an integrated, continuous, bench scale system with simulated flue gas having a *CO_2 concentration indicative of a NGPP* **(AOI-3F)** or a *CO_2 concentration indicative of the one in the selected industrial application* **(AOI-3G)**. The performance of the proposed carbon capture technology should be substantiated by providing experimental evidence measured under simulated flue gas conditions. Furthermore, the applicants should discuss the specific constituents in NGPP (**AOI-3F**) or industrial application (**AOI-3G**) flue gas that effect the carbon capture system proposed, and their expected short- and long-term effect on the overall carbon capture system performance.

4) **State Point Data Table**. Applicants are required to complete a State Point Data Table for their technology. Applicants shall prepare the State Point Data Table for flue gas conditions indicative of NGPPs **(AOI-3F)** or indicative of the selected industrial application **(AOI-3G)**, in the format provided in Appendix T of the FOA.

5) **Testing site selection**. Applicants are required to identify the location for conducting the engineering-scale testing of the carbon capture technology. The host site agreement will be a required deliverable 6 months after the project begins. The specific flue gas source must be located **exclusively in the United States**. Applicants must submit a letter of commitment from the host site for conducting the engineering-scale testing. The letter is required and must be signed by the person authorized to commit resources on behalf of the host site organization. The letter must demonstrate that this organization has agreed to participate in the project.

6) **Test Site Description and Carbon Capture Process Integration.** Applicants are required to describe the existing NGPP-indicative flue gas source facility **(AOI-3F)** or existing industrial facility **(AOI-3G)**, including, but not limited to, process diagrams, emissions profiles, and availability and quality of steam and/or waste heat (as applicable). A corresponding narrative is required to provide application reviewers a clear understanding of the proposed capture process and project from technical, cost effectiveness, and integrated systems perspectives. At a minimum, the description shall include the following:

    a. *Anticipated feed conditions* (e.g., pressure, temperature, flow rate, gas composition, and contaminant levels)
    b. *Electrical, water and waste management*. The applicants should describe how electricity, heat, water, and waste will be managed in the proposed engineering scale project, and tied into the existing host facility.
    c. *Contaminants Controls*. The applicants should describe how the flue gas contaminants (e.g., NOx, SOx, PM) are managed in the existing host facility and their potential effect on the carbon capture system.
    d. *CO_2 product disposition*. Although compression, transportation, and storage are not requested for engineering scale projects, applicants must demonstrate that the proposed CO_2 capture technology will produce a CO_2 stream of required temperature and quality suitable for cost-effective compression and transport/disposition of the stream, without adversely affecting existing operations, compressors, pipelines or geologic-storage formations.
    e. D*escription of the CO_2 capture equipment design concept* (e.g., membrane module architecture, absorber/desorber design, etc.).
    f. *Description of testing plan.* Activities to be performed and data to be collected to validate the performance of the technology in the proposed

test unit. Include a description of how the host site duty/operational cycle will be handled with respect to the 2 month continuous testing period.

7) **Brief descriptions of the existing process model for the capture technology and a Preliminary Techno- Economic Analysis (TEA) and Preliminary Life Cycle Analysis (LCA).** Summary reports describing existing process models and the preliminary TEA and LCA are to be included as separate files in the application package as noted in Section IV.B and in accordance with the applicable appendices.
8) **R&D Community Benefits Plan:** Applicants must submit a description of the proposed process for developing a community benefits plan that includes all of the elements discussed in Appendix L in a template provided in Appendix M.

Research Scope and Attributes that are Not of Interest

Areas considered to be outside the scope of **AOI-3F** and **AOI-3G** are specified in Section I.D. Applications that propose work in these areas will be considered nonresponsive and will not be evaluated.

Anticipated Technology Readiness Level

Beginning of project: TRL 5

End of project: TRL 6

Success Metric(s)

Success will be measured by completing of at least two months of engineering-scale testing of a transformational carbon capture technology at a facility under flue gas conditions indicative of a NGPP **(AOI-3F)** or at an industrial facility **(AOI-3G)** validating 95% or greater carbon capture efficiency and 95% or greater CO_2 purity, and attainment of the targeted TRL 6. In addition, development of rigorous, first principles, multi-scale, validated process models is required.

For **AOI-3F**, the final technoeconomic analysis should demonstrate significant progress towards a 30% reduction in cost of capture versus a reference NGPP with carbon capture for the reference carbon capture efficiency (i.e., 95%)[11].

For **AOI-3G**, the final technoeconomic analysis should demonstrate the economic viability of the proposed technology in terms of cost of capture and reduction in the increase in the cost of the industrial product that can justify its scale-up in a subsequent program. For most of the

[11] T. Schmitt, S. Leptinsky, M. Turner, A. Zoelle, M. Woods, T. Shultz, and R. James "Fossil Energy Baseline Revision 4a," National Energy Technology Laboratory, Pittsburgh, October 14, 2022.

industrial sectors of interest, reference cases for **AOI-3G** may be found in NETL's Industrial Capture Report, "Cost of Capturing CO_2 from Industrial Sources."[12]

Quantitative success metric targets will be established during negotiations with successful Applicants.

AOI-3H: Preliminary Front-End Engineering and Design Study AOIs

There are two subtopic areas for this AOI:

AOI-3H-a. ***Preliminary Front-End Engineering and Design Studies (pre-FEED) for Carbon Capture Systems at Existing (Retrofit) Domestic*** **NGPP**
This area of interest is soliciting pre-FEED studies of transformational carbon capture systems that separate 95% of CO_2 of the total emissions from domestic NGPP facilities. The proposed carbon capture system should be sized to capture emissions from the entire facility, or at a minimum, all the emissions from a particular unit with at least 95% capture efficiency. The applicants should select and propose a specific, existing (retrofit) NGPP, or a NGPP under construction that is expected to start commercial operation by the end of 2025. NGPPs are defined as natural gas combined cycle (NGCC), NGCC with combined heat and power (NGCC-CHP) and natural gas simple cycle (NGSC).

AOI-3H-b. Preliminary Front-End Engineering Design Studies (Pre-FEED) for Carbon Capture Systems at Hydrogen Production Facilities Using Coal, Mixed Coal/Biomass, or Natural Gas Feedstock

For AOI-3H-b, applicants will propose to execute and complete initial engineering design studies of commercial-scale, advanced hydrogen production systems with advanced carbon capture that separate, purify, and compress at least 95% of the total CO_2 emissions from the entire facility. Hydrogen production approaches of interest include gasification-based technologies, autothermal reforming, and chemical looping-based technologies. The combined hydrogen production system with carbon capture should be designed for a minimum capacity of 50 MWe equivalent of feedstock and be capable of producing hydrogen at a purity of 99.97%. Applicants should identify a specific operating facility if a retrofit is proposed, or a specific location for proposed new-build applications.

Applicants are required to propose teams that include the following, at a minimum:

AOI-3H-a	AOI-3H-b
NGPP operator/owner	Hydrogen production technology developer or licensor

[12] S. Hughes and A. Zoelle, "Cost of Capturing CO2 from Industrial Sources," National Energy Technology Laboratory, Pittsburgh, March 31, 2023.

Carbon capture technology developer or licensor	Carbon capture technology developer or licensor
Engineering, procurement and construction (EPC) engineering firm(s)	Engineering, procurement and construction (EPC) engineering firm(s)
	Existing hydrogen production facility operator/owner, if applicable

If an applicant is proposing team member(s), letter(s) of commitment from the member(s) are required and must be signed by the person authorized to commit resources on behalf of the organization. Letters should demonstrate the partner's level of commitment to the project, such as host site access, data access, and/or advisory services, etc.

The pre-FEED study will consist of process design and optimization, LCA, TEA, HAZOP (hazard operability) analysis, final design specifications, and other analyses, such as impacts of federal and state incentives (e.g., 45V and 45Q). To facilitate technology transfer, successful applications will be required to disseminate high-level findings, TEA, and LCA to the public in settings such as program specific annual review meetings. Applicants must demonstrate how deployment of the proposed carbon capture system **(AOI-3H-a)** or hydrogen production system **(AOI-3H-b)** will promote creation of clean energy or manufacturing jobs located in power plant communities that are economically distressed and/or have been disproportionately harmed by adverse environmental impacts.

Selected pre-FEED projects will perform activities including, but not limited to, those listed below:

a. **Pre-FEED Package.** Successful applicants will be required to prepare a FEED package in the format provided in Appendix W of the FOA. The proposed project must be consistent with AACE (Association of the Advancement of Cost Engineering) Class 4 designs. As such, process design, engineering, and optimization should have a project maturity level of 1-15% and cost estimate accuracy should be within -15% to -30% on the low side and +20% to +50% on the high side.

b. **Business case analysis.** Successful applicants will be required to prepare the business case analysis in the format provided in Appendix V of the FOA and submit it 90 days prior to project completion. If the plan includes the utilization of tax credits, the business case analysis shall include, at a minimum, details on the anticipated revenue and duration of the credits.

c. **Life Cycle Analysis (LCA).** Successful applicants will be required to prepare a LCA in the format provided in Appendix P(b) of the FOA to demonstrate robust accounting of full life cycle emissions. The initial LCA is due 120 days after award and should be updated as needed throughout the project period of performance. A final LCA should be submitted 90 days prior to project completion of the project.

d. **Environmental Health and Safety (EH&S) Analysis**. Successful applicants will be required to prepare an EH&S analysis of the proposed technologies and submit it 90 days prior to project completion in accordance with the format provided in Appendix Q of the FOA. EH&S analysis should include discussion regarding air and water emissions, water utilization, solid waste streams, and potential environmental impacts of the technology including toxicological effects and hazards of emissions and waste streams.

e. **Technology Maturation Plan (TMP).** Successful applicants will be required to prepare a TMP in the format provided in Appendix K of the FOA. Successful applicants will be required to submit a preliminary TMP 90 days after award, with a final TMP due 90 days prior to project completion.

f. **R&D Community Benefits Plan.** As a final deliverable, Recipients must report on R&D CBP accomplishments.

Technical Elements that Must be Included in Applications

For **AOI-3H-a and b**, Applicants are expected to include the following in the application materials:

1. **Carbon Capture Technology Description and Technology Readiness Level Evaluation.** Applicants are required to describe the proposed carbon capture technology including, but not limited to, process flow diagrams, properties of carbon capture materials, and governing chemical/physical processes. The applicants should provide data to support the readiness for commercial demonstration of the proposed carbon capture technology based on the Applicant's previous test results. Applicants shall prepare the State Point Data Table for the AOI relevant flue or process gas in the format provided in Appendix T of the FOA. **Applicants are required to provide complete information in the State Point Data Table to support the technology readiness of their approach.**

2. **Clean Hydrogen Production Technology Description and Technology Readiness Level Evaluation (AOI-3H-b only).** Applicants are required to describe the proposed clean hydrogen production technology including, but not limited to, process flow diagrams, heat and mass balances, properties of any catalysts, oxygen carriers or other key process materials, and governing chemical/physical processes. The description should also include details regarding how any carbon capture system will be integrated with the hydrogen production plant, including, but not limited to, any contaminant (e.g., NO_x, SO_x) abatement systems to be installed upstream of the carbon capture plant. The applicants should provide data to support the readiness of the proposed clean hydrogen production system based on the Applicant's previous test results. Applicants shall prepare the State Point Data Table for hydrogen production systems in the format provided in Appendix T of the FOA. **Applicants are required to provide complete information in the State Point Data Table to support the technology readiness of their approach.**

2. **Host site selection**. The host site must be located **exclusively in the United States.** The description of the host site should include the site's condition and existing infrastructure that will support the proposed advanced carbon capture system, availability of data and operating information as well as physical access to the plant by the applicant, and degree of commitment of the host site owner. The applicant should demonstrate the likelihood that any National Environmental Policy Act (NEPA) and/or permitting requirements at the host site can be satisfied with reasonable effort within the proposed performance period. Applicants must submit a letter of commitment from the host site. The letter is required and must be signed by the person authorized to commit resources on behalf of the host site organization. The letter must demonstrate that this organization has agreed to participate in the project. Applicants must select and propose an existing NGPP or a NGPP **(AOI-3H-a)** under construction that is expected to start commercial operation by the end of 2025 or an existing clean hydrogen production plant or a planned clean hydrogen production plant **(AOI-3H-b)**.

3. **NGPP Description and Carbon Capture Process Integration (AOI-3H-a only)**. Applicants are required to describe the existing or under construction NGPP including, but not limited to, process diagrams, and emissions profiles (e.g., location, concentration, contaminants, temperature, and pressure) of the CO_2-containing flue gas. The description should also include details regarding how the carbon capture system will be integrated with the NGPP, including, but not limited to, the proposed criteria pollutants (e.g., NO_x, SO_x) abatement systems to be installed upstream of the carbon capture plant. If multiple emission sources exist at the NGPP facility, the applicant should describe whether aggregation of the sources into one stream, upstream of the carbon capture facility, is proposed.

4. **CO_2 storage/Conversion options**. Applicants are required to identify and propose plausible options for CO_2 transportation, long duration carbon storage (i.e., geological storage or sub-surface mineralization) or CO_2 conversion/utilization into long-lasting products (e.g., synthetic aggregates, concrete, biochar, durable carbon products). If CO_2 conversion technology is proposed, it is expected that the applicants have already demonstrated their CO_2 conversion technology **at TRL 6 or above.** CO_2 pressure, CO_2 quality and quantity at the carbon capture plant "gate" should meet the requirements of the intended transport, carbon storage or CO_2 utilization/conversion solution. Examples of preferred carbon storage sites include but are not limited to: storage sites being developed under DOE's Carbon Storage Assurance Facility Enterprise (CarbonSAFE) initiative or other regional carbon capture and storage hubs under development. The applicants should discuss how the timeline of the carbon capture project will be linked to the development of the proposed CO_2 transportation, storage and/or conversion option.

5. **Summary of a Preliminary Techno-economic Analysis (TEA), a Preliminary Life Cycle Analysis (LCA) and a Preliminary Business Case Analysis (BCA).** Applicants are required to submit summary results of: (i) a preliminary TEA, (ii) a preliminary LCA, and (iii) a

preliminary BCA. The summary results should provide: (i) mass and energy balances, (ii) estimates of heating and cooling duties and electric power requirements, (iii) estimated capital operating costs, (iv) and objective variables. The preliminary TEA and preliminary BCA included in the application should be prepared based upon prior engineering design and costing work, and do not necessarily have to conform to the requirements in the appendices of the FOA. The preliminary LCA should be prepared in the format provided in Appendix P(b) of the FOA.

Summary of TEA, LCA and BCA scope and objective variables:

	AOI-3H-a	**AOI-3H-b**
Scope areas	Advanced carbon capture system	Clean hydrogen production system
	Balance of Plant	Advanced carbon capture system, if applicable
	Engineering, procurement and construction (EPC) engineering firm(s)	Balance of Plant
Objective Variables	Cost of Capture, Cost of Electricity Increase	Cost of Capture, Cost of Hydrogen Production, Hydrogen Carbon Intensity

6. **Summary of Process Models.** Applicants are also expected to provide a summary of the process models developed to-date for the proposed carbon capture technology that are used in the TEA, including but not limited to: (i) model assumptions, (ii) kinetics, mass-transfer, and heat-transfer correlations and their validation, (iii) model predictions for temperature/concentration profiles for major unit operations (e.g., absorber, desorber) and their validation with the experimental data.

6. **R&D Community Benefits Plan:** Applicants must submit a description of the proposed process for developing a community benefits plan that includes all of the elements discussed in Appendix L in a template provided in Appendix M.

Research Scope and Attributes that are Not of Interest

Not of Interest:

Areas considered to be outside the scope of **AOI-3H-a and AOI-3H-b** are specified in Section I.D.

Anticipated Technology Readiness Level

Beginning of project: TRL 6 or above for all carbon capture technologies **(AOI-3H-a and AOI-3H-b)** on the corresponding flue/process gases, TRL 5 or above for hydrogen production technologies **(AOI-3H-b).**

End of project: Same as beginning of project.

Success Metric(s)

Projects under **AOI-3H-a** will develop preliminary front-end engineering design studies (pre-FEED) for commercial-scale, advanced carbon capture systems that separate 95% of the total CO_2 emissions from existing, domestic NGPP. The proposed advanced carbon capture system should be sized to capture emissions from the entire facility, or at a minimum, all the emissions from a particular unit and produce a CO_2 product suitable for secure geological storage or CO_2 conversion/utilization into long-lasting products.

Projects under **AOI-3H-b** will develop preliminary front-end engineering design studies for a commercial scale clean hydrogen plant that produces hydrogen of 99.97% purity, and separates, purifies, and compresses at least 95% of the total CO_2 emissions from the entire facility. CO_2 product should be suitable for secure geological storage or CO_2 conversion/untilization into long-lasting products. These designs should provide the basis for the subsequent deployment of integrated carbon capture, utilization and storage projects that are targeting the 45Q tax credits and will be early adopters of the technology. Quantitative success metric targets will be established during negotiations with successful Applicants.

Appendix D – AOI-4 Carbon Transport and Storage

Demand for carbon capture and storage (CCS) technologies to meet climate goals is growing and will continue to grow in the foreseeable future. In a study led by Princeton University[13], by 2050, approximately 0.9 to 1.7 billion metric tons of CO_2 per year will need to be sequestered in order to achieve net-zero CO_2 emissions (net-zero). Five diverse pathways have been identified as essential to achieve net-zero by 2050. These pathways involve the utilization of varying energy technologies, including wind, solar, biomass, hydrothermal, nuclear, natural gas, and oil. All pathways rely on large-scale CO2 capture, transport, and utilization or storage in order to offset emissions.

Today, there are approximately 5,500 miles of existing CO_2 pipeline infrastructure across the United States[14]. To meet U.S emission reduction goals, the following injection and transport needs were identified by Princeton University[15]:

- By 2030: Injection rates of 65 million metric tons per annum (MMTPA) of CO2 and over 11,000 miles (19,000 kilometers [km]) of new pipeline infrastructure.
- By 2040: Injection rates of 435 MMTPA of CO2 and over 31,000 miles (51,000 km) of new pipeline infrastructure.
- By 2050: Injection rates of 929 MMTPA of CO2 and over 65,000 miles (106,000 km) of new pipeline infrastructure.

Under the current FOA opening, applications are solicited for AOI-4A. Projects awarded under AOI-4A will support advancements in infrastructure engineering and design needed for large-scale transport.

AOI-4A. Enhancing CO_2 Transport Infrastructure (ECO_2Transport): Pre-FEED Studies for Multimodal CO_2 Transfer Facilities

The United States will likely have to capture, transport, and permanently store significant quantities of CO_2 from stationary point sources and carbon dioxide removal (CDR) facilities to reach the nation's decarbonization goals of a net-zero GHG emissions economy by 2050. Studies demonstrate that new pipeline infrastructure needed by 2050 to connect these sources to long-term storage reservoirs includes 13,000 miles (21,000 km) of CO_2 transport trunk pipelines and over 52,000 miles (85,000 km) of spur pipelines[16].

For the purpose of AOI-4A, all transportation infrastructure defined below must facilitate the transport of anthropogenic CO_2:

[13] "Net-Zero America Project," Net-Zero America, 2024, https://netzeroamerica.princeton.edu/the-report.

[14] "Annual Report Mileage for Hazardous Liquid or Carbon Dioxide Systems." PHMSA, 2024. https://www.phmsa.dot.gov/data-and-statistics/pipeline/annual-report-mileage-hazardous-liquid-or-carbon-dioxide-systems.

[15] "Net-Zero America Project," Net-Zero America, 2024, https://netzeroamerica.princeton.edu/the-report.

[16] "Net-Zero America Project," Net-Zero America, 2024, https://netzeroamerica.princeton.edu/the-report.

- **Transport modes [modes of transport]:** Transportation capable of displacing large volumes of CO_2, including trucks, barges, ships, railways, and pipelines.

- **Multimodal CO_2 transportation:** The displacement of CO_2 by at least two modes of transport.

- **Intermodal CO_2 transportation:** A subset of multimodal transportation that transports CO_2 using standardized containers.

- **CO_2 transfer facility:** A facility that receives CO_2 from one or more transport modes and performs any of the operations necessary to continue transporting the CO_2 to its delivery point(s). These operations may include, but are not limited to, metering, dehydration, purification, liquefaction, storage, pumping, and loading/unloading. A transfer facility is typically bounded by a facility fence line.

- **Multimodal CO_2 transfer facility:** A type of CO_2 transfer facility that receives and transfers CO_2 via multiple modes of transport (e.g., receive from barge and truck and transfer to a pipeline).

- **Intermodal CO_2 transfer facilities:** A type of multimodal CO_2 transfer facility that receives and transfers CO_2 via standardized containers. The CO_2 container is transferred between modes (e.g., receive from a railcar and transfer to a barge).

Technology for transporting CO_2 through pipelines is relatively mature. However, large volumes of CO_2 could be more effectively transported if displaced over a variety of transport modes. For example, dedicated pipelines may be the economical transport choice for large CO_2 sources such as fossil-fueled power plants, but truck or rail may be the optimal transport mode for smaller-volume sources such as direct air capture facilities. The final destination for this CO_2 may be a dedicated large-scale geologic storage facility served by a pipeline or barge. Alternatively, small-volume utilization sites may benefit from the ability to receive CO_2 via truck or rail rather than from a dedicated pipeline. The quality of CO_2 received from source sites may differ from the quality requirements (e.g., temperature, pressure, impurities) of destination sites.

Fully-commercial CCS and CDR projects will require adequate and dynamic CO_2 transportation infrastructure to transfer CO_2 from a variety of sources to a variety of sinks. In order to interface, process and condition, temporarily store, and connect various CO_2 transport modes, multimodal transfer facilities are essential. However, many industries in the United States do not currently have the experience or technology to accommodate the consolidation and facilitation of multimodally transported CO_2.

Achieving the United States 2030 emission reduction target will require transport capacities to significantly scale up within this decade, thus necessitating the development of adaptable and long-term CO_2 transport infrastructure. Executing this accelerated development in a manner that

is cost-efficient and sustainable requires effective strategic planning, coordination between multiple transportation systems, and continuous focus on safe and practical design, construction, and operation.

I. Research Sought

The objectives for **AOI-4A** are complementary to the objectives of *DE-FOA-0002730, Carbon Capture Technology Program, Front-End Engineering and Design for Carbon Dioxide Transport*: accelerate and enable initial planning, design, and economic analysis for transport of CO_2. In support of developing safe, cost-efficient, and long-term transportation options for various types of CO_2 sources, Applicants are sought to propose to develop preliminary FEED (Pre-FEED) studies for a real-world scenario, commercial-scale multimodal CO_2 transfer facility (referred to as multimodal transfer facility herein). It is expected that the Pre-FEED studies will provide insight into multimodal transfer facility design and placement considerations, risk identification and mitigation, and resource requirements.

Pre-FEED study projects awarded under **AOI-4A** will consider how multimodal transfer facilities will be strategically located, designed, and deployed to connect multimodal CO_2 infrastructure in a manner that serves the efficient, equitable, and environmentally responsible expansion of CCS and CDR operations. Projects will consider how the multimodal transfer facility will prioritize societal considerations and impacts (SCI), as well as meaningful community engagement, throughout planning, development, and operation. Multimodal transfer facilities considered in the pre-FEED studies will possess the following characteristics:

- Support transportation of anthropogenic CO_2 from a minimum of one (1) carbon capture source to one (1) or more carbon sinks.
    - Although not specifically required, Applications that contain two (2) or more anthropogenic sources of CO_2 are desired.
    - Carbon capture sources may include a combination of CO_2 removal (e.g., direct air capture and biomass carbon removal and storage (BiCRS)) and point sources (e.g., industrial and power generation).
    - Carbon sinks may include applicable secure geologic storage location(s) and/or one or more CO_2 conversion location(s).
- Facilitate and supports reception and/or offtake from at least two (2) modes of transport.
- Capacity to receive, process, and discharge at least 1 MMTPA of CO_2.
- Operate as an open access or common carrier system.
- Consider the CO_2 sources processing and metering conditions, including compression, dehydration, liquification, purification, and custody transfer metering to meet applicable transport, permanent geologic storage, or conversion product quality specifications.
- Accommodate the intended CO_2 temperature, pressure, quality, and quantities required by multiple transportation modalities and the intended storage and/conversion location(s).
- Adhere and comply with all federal, state, and local regulations.

DOE proposes to provide funding for up to five (5) AOI-4A Pre-FEED study projects based on their technical merit, commercial and regulatory viability, and strategic value to support the CCS and CDR industry. The projects are anticipated to be awarded for a period of performance of one year and to be federally funded at a maximum of $800,000 per award, dependent upon scale, transport interface(s), terrain, region, size, volume, conversion, storage parameters, and other factors the Applicant appropriately and sufficiently justifies within their Application package.

Applicants should develop a strong and well-substantiated case to justify the investment for a proposed multimodal transfer facility. The Application should include only one real-world, multimodal transfer facility scenario; demonstrate the capture, transportation, and storage/conversation options regionally available; and capture the applicable local, state and federal regulatory landscape. A complete list of technical requirements for Applications for AOI-4A is included below under **Appendix D. Section III. Technical Elements That Must Be Included in Applications.**

II. Scope of Work

If awarded, selected Pre-FEED projects will perform the following scope of work needed to produce pre-FEED study deliverables:

1. **Project execution plan** that details the timeline, critical items, decisions points, and significant milestones necessary to advance the project through the stages of pre-FEED, FEED, detailed design, procurement, construction, and start-up.

2. **Project cost estimate.** Design of the transfer facility shall support an itemized capital cost (CAPEX) and operating cost (OPEX) estimate consistent with Association of the Advancement of Cost Engineering (AACE) Class 4 with an expected accuracy range of -15% to -30% on the low side and +20% to +50% on the high side. The cost estimate should include a basis of estimate for each item.

3. **Land acquisition plan** that details the timeline, critical items, decisions points, and significant milestones necessary to acquire the necessary easements and land rights.

4. **Permitting plan** that includes appropriate agencies, permits needed, and estimated timeframe for submitting applications and obtaining identified permits.

5. **Hazard Identification Study (HAZID)** that identifies any potential hazards and impacts of identified hazards on the proposed facility.

6. **Early Project Design Basis (EPDB) report** that includes, at a minimum:

    a. **Facility operating capacity** including the facility design capacity and temporary storage (if applicable)

b. **Overview of the relevant local, state, and federal codes and regulations** applicable to the project.

c. **Facility siting study** that considers, at a minimum:
   i. Conceptual Emergency Response Plan (ERP) and evacuation routes;
   ii. Environmentally sensitive areas, high consequence areas, major proximal hazards (e.g., population centers, freeways, waterbodies, wetlands, lakes, etc.);
   iii. Geology (e.g., terrain and soil properties), seismicity, and climate (temperature, humidity, precipitation, prevailing wind direction, severe weather events);
   iv. Impact of on-site release to the subsurface and areas beyond the fence line of the transfer facility;
   v. Proximity to existing or proposed CO_2 source(s), permanent storage or conversion sites, transport infrastructure (e.g., pipelines, railroads, highways, barges, ships etc.), and utilities (e.g., power, water, fuel, communications, etc.);
   vi. Land and resource availability for future construction or expansion within the facility or external to the facility.

d. **Map(s) of the proposed multimodal transfer facility** showing receipt and delivery routes, CO_2 sink(s), CO_2 source(s), roadways, railways, nearby industrial facilities, population centers, waterways, high consequence areas (HCAs), and other relevant details.

e. **Operability and Reliability Plan** for the proposed multimodal transfer facility that includes, at a minimum:
   i. Operating modes and unit operational envelopes (e.g., turndown ratio);
   ii. Redundancy and sparing philosophy;
   iii. Operability and reliability targets; and
   iv. Management plan for potential intermittency of CO_2 sources and sinks.

f. **Proposed CO_2 product quality specification** at the receipt and delivery points with detailed rationale. At a minimum, the specification must list permissible temperature, pressure, and impurity limits. Impurity limits must include:
   i. Type (e.g., carbon oxides, water, oxygen, sulfur oxides, nitrogen oxides, hydrogen sulfides, organics, amines, particulate matter, etc.);
   ii. Unit(s) of measurement (e.g., mol-%, ppm-mol, micrometer, etc.); and
   iii. Acceptable limits (e.g., minimum 99 mol-% carbon dioxide, < 30ppm-mol water, etc.).

g. **Process Flow Diagrams (PFD) and a heat and material balance** for all major process streams entering the facility, within the facility, and exiting the facility. The PFD shall be accompanied with a functional description / process narrative.

h. **List, description, and preliminary specifications for**:
    i. Major mechanical, processing, and electrical equipment;
    ii. Required utility systems (water, fuel, communications, etc.); and
    iii. Buildings (occupied and unoccupied).

i. **Preliminary General Arrangement (GA) drawing** of the proposed multimodal transfer facility. The GA shall depict the quantity, location, and arrangement of:
    i. Major mechanical/processing equipment, such as: filters, separators, pigging equipment, dryers, engines, pumps, compressors, turbines, dehydration equipment, heat exchangers, chillers, towers, meters, storage vessels, emergency shutdown valves, major piping, utility systems, custody transfer stations, loading (filling) and unloading (emptying) terminals;
    ii. Major buildings and electrical equipment, such as: compressor buildings, pump buildings, motor control centers, control rooms, power distribution centers, emergency generators, substations, other occupied and unoccupied buildings;
    iii. Civil/structural infrastructure, such as: access roads, facility roads, pipe racks, laydown yards, parking, and other structures; and
    iv. Equipment and structures shall be arranged: to manage risks from explosions, fires, and releases to on-site personnel; to permit operation, maintenance, and replacement.

j. **Preliminary electrical one-line diagram and electrical load list**.

7. **Environmental, Safety and Health (ES&H) analysis**. Successful applicants will be required to prepare an ES&H analysis of the proposed project in accordance with the general format provided in Appendix Q. ES&H analysis should include a discussion regarding emissions to air and water, solid waste streams, water use, and potential environmental and health impacts of the project.

8. **Preliminary long lead material and equipment list**.

9. Updated **Business Case Analysis** due in the Final Scientific/Technical Report.

10. Updated **Regulatory Plan Analysis** due in the Final Scientific/Technical Report.

11. **Projected use for the multimodal transfer facility** over the next 30 years including types of CO_2 sources and sinks in the present and future that will be available to utilize the facility.

12. **R&D Community Benefits:** As a final deliverable, Recipients must report on R&D CBP accomplishments.

DOE is working with our partners including the U.S. Department of Interior (DOI) Bureau of Safety and Environmental Enforcement (BSEE) and Bureau of Ocean Energy Management (BOEM), and U.S. Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration (PHMSA), Maritime Administration (MARAD), Federal Highway Administration (FHWA), and Federal Railroad Administration (FRA) to ensure a safe and reliable CO_2 transport network that supports the deployment of CCS and CDR. Any information developed as part of the pre-FEED study may be used to inform the development of critical safety and risk requirements for multimodal transfer facilities.

III. Technical Elements that Must be Included in Applications

For **AOI-4A**, Applicants must address the following technical requirements:

A. Summary of a completed scoping/conceptual/pre-feasibility study

1. Multimodal CO_2 transfer facility site selection

   i. The Applicant must propose a multimodal transfer facility site within the United States. All proposed transportation infrastructure must adhere and comply with all federal, state, and local regulations.

   ii. A site description and map must be provided, with sufficient resolution to discern population centers, municipal borders including counties, and relevant proximal infrastructure. The site description should also identify any environmentally sensitive areas, HCAs, and major proximal hazards (including population centers, freeways, waterbodies, wetlands, lakes, etc.). The Application must clearly define the site boundaries and describe how site boundaries were determined on the basis of the above considerations.

   iii. The Application must describe the technical, economic, regulatory, permitting, environmental, safety, community, and DEIA considerations that were used to identify and select the host site for the proposed facilities, including a preliminary analysis of alternative sites that were considered but were not selected. The Applicant should demonstrate the likelihood that any National Environmental Policy Act (NEPA) and/or permitting requirements at the host site can be satisfied with reasonable effort within the proposed performance period.

   Applicants are encouraged to propose site that embraces DEIA standards, promotes environmental justice, provides broad positive community impacts, and fosters relationships that support existent CCS and CDR projects. The Applicant must discuss how the proposed site considered climate change related risks and opportunities within the lifespan of the proposed infrastructure.

iv. A commitment letter for the proposed multimodal CO_2 transfer facility host site must be provided. The letter(s) must demonstrate the resource owner's level of commitment to the project along with confirming that the site to be evaluated is located in the United States. Letter(s) must be signed by the person authorized to commit resources on behalf of the organization and be provided in PDF format. The letter(s) should be saved under a single file named "CIL.pdf". Select "Add Optional Other Attachment" to attach.

2. Proposed CO_2 sources, sinks, and connective transport infrastructure (*note, the design of the sources, sinks, or connective transport infrastructure is **not** within the project scope)*
    i. The Application must describe the target anthropogenic CO_2 source(s) that will supply CO_2 to the transfer facility. Justification for the selected source(s) must be provided. Descriptions of each source should include, at minimum, the following information:
        - Source location, industry, and name;
        - Type of capture system;
        - Required post capture processing (e.g., compression, dehydration, purification);
        - CO_2 physical and chemical characteristics (e.g., temperature, pressure, flow rate, fluid composition including impurities); and
        - Physical readiness of the source to supply CO_2 to the transfer facility (e.g., existing or planned infrastructure, community readiness, etc.).

        Applicants must note which of the above source information was not available. Although not specifically required, Applications that contain two (2) or more anthropogenic sources of CO_2 are desired.

    ii. The Application must describe the target sink(s) (i.e., CO_2 geologic storage and/or conversion site(s)) that will accept the CO_2 delivered from the transfer facility. Justification for the selected sinks must be provided. Descriptions of each sink should include, at minimum, the following information:
        - Sink location;
        - Physical readiness of the sink to accept CO_2 delivered from the transfer facility:
            a. For geologic storage sites, this may include degree to which the site has been characterized, existing or planned infrastructure, community readiness, etc.
            b. For conversion sites, this may include existing or planned infrastructure, community readiness, etc.

- Required CO_2 physical and chemical characteristics for the storage/conversion site (e.g., temperature, pressure, flow rate, fluid composition including impurities).

Applicants must note which of the above sink information was not available.

iii. The application must describe existing, repurposed, or new transport infrastructure required to transport CO_2 from the source(s) to the transfer facility and from the transfer facility to the sink(s). Justification for the selected transport modes and a discussion of whether the transport modes are open access or common carrier must be provided. Descriptions of each existing, repurposed, or new transport structure should include, at minimum, the following information:
   - Map of the transport routes;
   - Transport modes;
   - Transport capacity;
   - Physical readiness of the transport system to transport CO2 from the sources to the transfer facility and from the transfer facility to the sink (e.g., stage of development, quality of existing infrastructure, community readiness, etc.); and
   - Required CO_2 physical and chemical characteristics for the transport infrastructure (e.g., temperature, pressure, transport capacity, fluid composition including impurities).

   Applicants must note which of the above transport structure information was not available.

iv. Applicants may propose a facility that connects to CO_2 transportation infrastructure that crosses international borders. However, costs associated with transportation infrastructure outside of the United States will not be reimbursed by DOE or recognized as cost share under the Financial Assistance award. Applications and awarded projects that include international infrastructure connections will be expected describe and detail all international transport infrastructure per the AOI-4A scope criteria and requirements.

v. Applicants are encouraged to provide letters of commitment or interest for the proposed CO_2 source, CO_2 conversion, and/or CO_2 geologic storage location(s).

   The letter(s) must demonstrate the resource owner's level of commitment to the project along with confirming that the site to be evaluated is located

in the United States. Letter(s) must be signed by the person authorized to commit resources on behalf of the organization and be provided in PDF format.

The letter(s) should be saved under a single file named "CIL.pdf". Select "Add Optional Other Attachment" to attach.

3. The application must include the following multimodal transfer facility design basis:
    i. A high-level summary of the transfer facility process design basis. This must include a block flow diagram or preliminary process flow diagram that summarizes the transfer facility process design basis (e.g., facility capacity, major process stream data, metering, pumping/compression, dehydration, purification, temporary storage, loading/unloading requirements, etc.) and selected technology providers (if known).

    ii. A preliminary site layout plan including major equipment and buildings.

    iii. A discussion of how the transfer facility will remove impurities from CO_2 sources, with consideration of acceptable impurity limits within the transfer facility and downstream of the transfer facility (e.g., transport infrastructure, geologic storage, conversion facility).

    iv. A description of how the transfer facility will safely transfer CO_2 between transport modes.

4. A preliminary risk assessment and a health, safety, and environmental (HSE) analysis that includes an assessment of technical, economic, regulatory, permitting, community, and HSE risks and challenges during construction and operation of the transfer facility. The risk assessment should also identify relevant emergency response considerations for any proximal industrial activities, population centers, and environmentally sensitive areas. The HSE analysis should include a discussion of the Applicant's plan to address HSE risks and impacts over the lifetime of the facility. HSE risks and impacts include but are not limited to human health and safety; impacts to air, soil, and water; generation and disposal of hazardous materials; and an increase in overall greenhouse gas emissions (carbon dioxide equivalent, CO_2e).

5. A preliminary project cost estimate. The capital cost estimate must be consistent with Association of the Advancement of Cost Engineering (AACE) Class 5 with an expected accuracy range of -20% to -50% on the low side and +30% to +100% on the high side. The cost estimate should include a basis of estimate for each item.

B. **Preliminary business case analysis.** The application must include a preliminary business case analysis in accordance with the requirements and format provided in FOA Appendix X. This preliminary business case analysis must demonstrate an understanding of the current and projected commercial viability of the proposed project. This analysis should identify the market size, business drivers, rationale for the proposed sources and sinks to be connected, projected revenue sources, expenses, owner/operator strategy, anticipated return on investment (ROI), growth opportunities in the region(s) in which the proposed project is located, along with a list of key economic and financial assumptions.

The preliminary business case analysis must also clearly state whether the multimodal transfer facility will be an open access or common carrier infrastructure to all interested shippers and if capacity for future expansion has been considered. Applicants should provide a projected use for the transfer facility over the next 30 years including types of CO_2 sources and sinks in the present and future that will be available to utilize the facility.

Successful Applicants will be required to submit a final Business Case Analysis within 90 days of project completion that shall be prepared in the format provided in FOA Appendix X.

C. **Regulatory Plan Analysis**. Applicants are required to submit a Regulatory Plan Analysis of the proposed project in accordance with the requirements and format provided in FOA Appendix Y. The Regulatory Plan Analysis may be limited to the boundary of the facility itself and does not need to consider the entire transport network inbound from CO_2 sources or outbound to CO_2 sinks.

The Regulatory Plan shall set forth the applicant's plans and actions to engage with local, state, and federal regulators and receive the necessary permits and regulatory approvals for the proposed project. The Regulatory Plan Analysis must demonstrate how the deployment of the proposed facility will meet or exceed local, state, and federal regulatory requirements, and shall identify the permits and regulatory approvals needed to construct and operate the proposed facility. In conjunction with the Community Benefits Plan, the Regulatory Plan Analysis shall identify if community and stakeholder support has been obtained or opposition has been received by the applicant.

Successful applicants will be required to submit a final Regulatory Plan Analysis within 90 days of project completion that shall be prepared in the format provided in FOA Appendix Y.

D. R&D Community Benefits Plan. Applicants must submit a community benefits plan that includes all of the elements discussed in FOA Appendix L in a template provided in Appendix M.

IV. Research Scope and Attributes that are Not of Interest

Areas considered to be outside the scope of AOI-4A are listed in Section I.D. (Applications Specifically Not of Interest) of the FOA. Applications that propose work in these areas will be considered non-responsive and will not be evaluated.

V. Anticipated Technology Readiness Level

Not Applicable. Technologies described in applications to this FOA will incorporate mature applied technologies (TRL 9 and above) that are broadly deployed; therefore, no advancements in Technology Readiness Levels are required.

VI. Success Metric(s)

Successful projects will complete a Pre-FEED study for a multimodal transfer facility. The final project report should demonstrate if a proposed design is applicable for a full FEED study based on desktop evaluations of engineering design, costs, regulatory considerations and decarbonization incentives and policies.

Appendix E - Cost Share Information

Cost Sharing or Cost Matching

The terms “cost sharing” and “cost matching” are often used synonymously. Even the DOE Financial Assistance Regulations, 2 CFR 200.306, use both of the terms in the titles specific to regulations applicable to cost sharing. DOE almost always uses the term “cost sharing,” as it conveys the concept that non-federal share is calculated as a percentage of the Total Project Cost. An exception is the State Energy Program Regulation, 10 CFR 420.12, State Matching Contribution. Here “cost matching” for the non-federal share is calculated as a percentage of the Federal funds only, rather than the Total Project Cost.

How Cost Sharing Is Calculated

As stated above, cost sharing is calculated as a percentage of the Total Project Cost. FFRDC/NL costs must be included in Total Project Costs.

The following is an example of how to calculate cost sharing amounts for a project with $1,000,000 in federal funds with a minimum 20% non-federal cost sharing requirement:

- Formula: Federal share ($) divided by Federal share (%) = Total Project Cost
  Example: $1,000,000 divided by 80% = $1,250,000

- Formula: Total Project Cost ($) minus Federal share ($) = Non-federal share ($)
  Example: $1,250,000 minus $1,000,000 = $250,000

- Formula: Non-federal share ($) divided by Total Project Cost ($) = Non-federal share (%)
  Example: $250,000 divided by $1,250,000 = 20%

What Qualifies For Cost Sharing

While it is not possible to explain what specifically qualifies for cost sharing in one or even a couple of sentences, in general, if a cost is allowable under the cost principles applicable to the organization incurring the cost and is eligible for reimbursement under an DOE grant or cooperative agreement, then it is allowable as cost share. Conversely, if the cost is not allowable under the cost principles and not eligible for reimbursement, then it is not allowable as cost share. In addition, costs may not be counted as cost share if they are paid by the Federal Government under another award unless authorized by Federal statute to be used for cost sharing.

The rules associated with what is allowable as cost share are specific to the type of organization that is receiving funds under the grant or cooperative agreement, though are generally the same for all types of entities. The specific rules applicable to:

- FAR Part 31 for For-Profit entities, (48 CFR Part 31); and
- 2 CFR Part 200 Subpart E - Cost Principles for all other non-federal entities.

In addition to the regulations referenced above, other factors may also come into play such as timing of donations and length of the project period of performance. For example, the value of ten years of donated maintenance on a project that has a project period of performance of five years would not be fully allowable as cost share. Only the value for the five years of donated maintenance that corresponds to the project period of performance is allowable and may be counted as cost share.

Additionally, DOE generally does not allow pre-award costs for either cost share or reimbursement when these costs precede the signing of the appropriation bill that funds the award. In the case of a competitive award, DOE generally does not allow pre-award costs prior to the signing of the Selection Statement by the DOE Selection Official.

General Cost Sharing Rules on a DOE Award

1. Cash Cost Share – encompasses all contributions to the project made by the recipient or subrecipient(s), for costs incurred and paid for during the project. This includes when an organization pays for personnel, supplies, equipment for their own company with organizational resources. If the item or service is reimbursed for, it is cash cost share. All cost share items must be necessary to the performance of the project.

2. In-Kind Cost Share – encompasses all contributions to the project made by the recipient or subrecipient(s) that do not involve a payment or reimbursement and represent donated items or services. In-Kind cost share items include volunteer personnel hours, donated existing equipment, donated existing supplies. The cash value and calculations thereof for all In-Kind cost share items must be justified and explained in the Cost Share section of the project Budget Justification. All cost share items must be necessary to the performance of the project. If questions exist, consult your DOE contact before filling out the In-Kind cost share section of the Budget Justification.

3. Funds from other federal sources MAY NOT be counted as cost share. This prohibition includes FFRDC subrecipients. Non-federal sources include any source not originally derived from federal funds. Cost sharing commitment letters from subrecipients must be provided with the original application.

4. Fee or profit, including foregone fee or profit, are not allowable as project costs (including cost share) under any resulting award. The project may only incur those costs that are allowable and allocable to the project (including cost share) as determined in accordance with the applicable cost principles prescribed in FAR Part 31 for For-Profit entities and 2 CFR Part 200 Subpart E - Cost Principles for all other non-federal entities.

DOE Financial Assistance Rules 2 CFR Part 200 as amended by 2 CFR Part 910

As stated above, the rules associated with what is allowable cost share are generally the same for all types of organizations. Following are the rules found to be common, but again, the specifics are contained in the regulations and cost principles specific to the type of entity:

(A) Acceptable contributions. All contributions, including cash contributions and third party in-kind contributions, must be accepted as part of the Prime Recipient's cost sharing if such contributions meet all of the following criteria:

(1) They are verifiable from the recipient's records.

(2) They are not included as contributions for any other federally-assisted project or program.

(3) They are necessary and reasonable for the proper and efficient accomplishment of project or program objectives.

(4) They are allowable under the cost principles applicable to the type of entity incurring the cost as follows:

a. For-profit organizations. Allowability of costs incurred by for-profit organizations and those nonprofit organizations listed in Attachment C to OMB Circular A–122 is determined in accordance with the for-profit cost principles in 48 CFR Part 31 in the Federal Acquisition Regulation, except that patent prosecution costs are not allowable unless specifically authorized in the award document. (v) Commercial Organizations. FAR Subpart 31.2—Contracts with Commercial Organizations

b. Other types of organizations. For all other non-federal entities, allowability of costs is determined in accordance with 2 CFR Part 200 Subpart E.

(5) They are not paid by the Federal Government under another award unless authorized by Federal statute to be used for cost sharing or matching.

(6) They are provided for in the approved budget.

(B) Valuing and documenting contributions

(1) Valuing recipient's property or services of recipient's employees. Values are established in accordance with the applicable cost principles, which mean that amounts chargeable to the project are determined on the basis of costs incurred. For real property or equipment used on the project, the cost principles authorize depreciation or use charges. The full value of the item may be applied when the item

will be consumed in the performance of the award or fully depreciated by the end of the award. In cases where the full value of a donated capital asset is to be applied as cost sharing or matching, that full value must be the lesser or the following:

a. The certified value of the remaining life of the property recorded in the recipient's accounting records at the time of donation; or
b. The current fair market value. If there is sufficient justification, the Contracting Officer may approve the use of the current fair market value of the donated property, even if it exceeds the certified value at the time of donation to the project. The Contracting Officer may accept the use of any reasonable basis for determining the fair market value of the property.

(2) Valuing services of others' employees. If an employer other than the recipient furnishes the services of an employee, those services are valued at the employee's regular rate of pay, provided these services are for the same skill level for which the employee is normally paid.

(3) Valuing volunteer services. Volunteer services furnished by professional and technical personnel, consultants, and other skilled and unskilled labor may be counted as cost sharing or matching if the service is an integral and necessary part of an approved project or program. Rates for volunteer services must be consistent with those paid for similar work in the recipient's organization. In those markets in which the required skills are not found in the recipient organization, rates must be consistent with those paid for similar work in the labor market in which the recipient competes for the kind of services involved. In either case, paid fringe benefits that are reasonable, allowable, and allocable may be included in the valuation.

(4) Valuing property donated by third parties.

a. Donated supplies may include such items as office supplies or laboratory supplies. Value assessed to donated supplies included in the cost sharing or matching share must be reasonable and must not exceed the fair market value of the property at the time of the donation.

b. Normally only depreciation or use charges for equipment and buildings may be applied. However, the fair rental charges for land and the full value of equipment or other capital assets may be allowed, when they will be consumed in the performance of the award or fully depreciated by the end of the award, provided that the Contracting Officer has approved the charges. When use charges are applied, values must be determined in accordance with the usual accounting policies of the recipient, with the following qualifications:

i. The value of donated space must not exceed the fair rental value of comparable space as established by an independent appraisal of comparable space and facilities in a privately-owned building in the same locality.
ii. The value of loaned equipment must not exceed its fair rental value.

(5) Documentation. The following requirements pertain to the recipient's supporting records for in-kind contributions from third parties:

a. Volunteer services must be documented and, to the extent feasible, supported by the same methods used by the recipient for its own employees.

b. The basis for determining the valuation for personal services and property must be documented.

Appendix F – Waiver Requests: Foreign Entity Participation and Performance of Work in the United States

iv. Waiver for Foreign Entity Participation as the Prime Recipient

As set forth in Section III, "Eligibility Information", all Prime Recipients receiving funding under this FOA must be incorporated (or otherwise formed) under the laws of a State or territory of the United States. To request a waiver of this requirement, an applicant must submit an explicit waiver request in the Full Application.

Overall, the applicant must demonstrate to the satisfaction of DOE that it would further the purposes of this FOA and is otherwise in the economic interests of the United States to have a foreign entity serve as the Prime Recipient. A request to waive the *Foreign Entity Participation as the Prime Recipient* requirement must include the following:

- Entity name;
- The rationale for proposing a foreign entity to serve as the Prime Recipient;
- Country of incorporation; and the extent, if any, the entity is state owned or controlled;
- A description of the project's anticipated contributions to the US economy;
  - How the project will benefit U.S. research, development and manufacturing, including contributions to employment in the U.S. and growth in new markets and jobs in the U.S.;
  - How the project will promote domestic American manufacturing of products and/or services;
- A description of how the foreign entity's participation as the Prime Recipient is essential to the project;
- A description of the likelihood of Intellectual Property (IP) being created from the work and the treatment of any such IP;
- Countries where the work will be performed (Note: if any work is proposed to be conducted outside the U.S., the applicant must also complete a separate request for waiver of the Performance of Work in the United States requirement).

DOE may also require:

- A risk assessment with respect to IP and data protection protocols that includes the export control risk based on the data protection protocols, the technology being developed and the foreign entity and country. These submissions could be prepared by the project lead (if not the prime recipient), but the prime recipient must make a representation to DOE as to whether it believes the data protection protocols are adequate and make a representation of the risk assessment – high, medium or low risk of data leakage to a foreign entity.
- Additional language be added to any agreement or subagreement to protect IP, mitigate risk or other related purposes.

DOE may require additional information before considering the waiver request.

The applicant does not have the right to appeal DOE's decision concerning a waiver request.

v. Waiver for Performance of Work in the United States (Foreign Work Waiver)

As set forth in Section IV, "Application and Submission Information", all work under DOE funding agreements must be performed in the United States. This requirement does not apply to the purchase of supplies and equipment, so a waiver is not required for foreign purchases of these items. However, the Prime Recipient should make every effort to purchase supplies and equipment within the United States. There may be limited circumstances where it is in the interest of the project to perform a portion of the work outside the United States. To seek a waiver of the Performance of Work in the United States requirement, the applicant must submit an explicit waiver request in the Full Application. A separate waiver request must be submitted for each entity proposing performance of work outside of the United States.

Overall, a waiver request must demonstrate to the satisfaction of DOE that it would further the purposes of this FOA and is otherwise in the economic interests of the United States to perform work outside of the United States. A request to waive the *Performance of Work in the United States* requirement must include the following:

- The rationale for performing the work outside the U.S. ("foreign work");
- A description of the work and the percentage of the direct labor (including subrecipients) proposed to be performed outside the U.S.;
- An explanation as to how the foreign work is essential to the project;
- A description of the anticipated benefits to be realized by the proposed foreign work and the anticipated contributions to the US economy;
    - The associated benefits to be realized and the contribution to the project from the foreign work;
    - How the foreign work will benefit U.S. research, development and manufacturing, including contributions to employment in the U.S. and growth in new markets and jobs in the U.S.;
    - How the foreign work will promote domestic American manufacturing of products and/or services;
- A description of the likelihood of Intellectual Property (IP) being created from the foreign work and the treatment of any such IP;
- The total estimated cost (DOE and Recipient cost share) of the proposed foreign work;
- The countries in which the foreign work is proposed to be performed; and
- The name of the entity that would perform the foreign work, by country (if more than one foreign country is proposed).

- Information about the entity(ies) involved in the work proposed to be conducted outside the United States. (i.e., entity seeks a waiver and the entity(ies) that will conduct the work).

DOE may require additional information before considering the waiver request.

The applicant does not have the right to appeal DOE's decision concerning a waiver request.

Appendix G – Buy America Requirements for Infrastructure Projects Required Use of American Iron, Steel, Manufactured Products, and Construction Materials - Buy America Requirements for Infrastructure Projects

A. Definitions
For purposes of the Buy America Requirements, based both on statute and OMB Guidance Document dated April 18, 2022, the following definitions apply:

Components See 2 CFR 184.3 Definitions

Construction materials See 2 CFR 184.3 Definitions

"Buy America Preference," "Buy America Requirement," or "Domestic Content Procurement Preference" means the requirements set forth in section 70914 of the Build America, Buy America Act, which requires the head of each Federal agency to ensure that none of the funds subject to the requirements are made available for a Federal award for an infrastructure project may be obligated unless all of the iron, steel, manufactured products, and construction materials incorporated into the project are produced in the United States.

Infrastructure See 2 CFR 184.4(c) and (d)

Manufactured Products See 2 CFR 184.3 Definitions

Predominantly of Iron or Steel See 2 CFR 184.3 Definitions

Infrastructure Project See 2 CFR 184.3 Definitions

B. Buy America Requirements for Infrastructure Projects ("Buy America" requirements)
None of the project funds (includes federal share and recipient cost share) may be used for a project for infrastructure unless:

> (1) all iron and steel used in the project are produced in the United States--this means all manufacturing processes, from the initial melting stage through the application of coatings, occurred in the United States;
>
> (2) all manufactured products used in the project are produced in the United States—this means the manufactured product was manufactured in the United States; and the cost of the components of the manufactured product that are mined, produced, or manufactured in the United States is greater than 55 percent of the total cost of all components of the manufactured product, unless another standard for determining the

minimum amount of domestic content of the manufactured product has been established under applicable law or regulation. See 2 CFR 184.5 for determining the cost components for manufactured products; and

(3) all construction materials[17] are manufactured in the United States—this means that all manufacturing processes for the construction material occurred in the United States. See 2 CFR 184.6 for construction material standards.

The Buy America Requirements only apply to those articles, materials, and supplies that are consumed in, incorporated into, or affixed to the infrastructure in the project. As such, it does not apply to tools, equipment, and supplies, such as temporary scaffolding, brought to the construction site and removed at or before the completion of the infrastructure project. Nor does the Buy America Requirements apply to equipment and furnishings, such as movable chairs, desks, and portable computer equipment, that are used at or within the finished infrastructure project, but are not an integral part of the structure or permanently affixed to the infrastructure project.

The Buy America Requirement only applies to an article, material, or supply classified into one of the following categories* based on its status at the time it is brought ot he work site for incorporation into an infrastructure project:

I. Iron or steel products;
II. Manufactured products; or
III. Construction materials.

The Buy America Requirement only applies to the iron or steel products, manufactured products, and construction materials used for the construction, alteration, maintenance, or repair of public infrastructure in the United States when those items are consumed in, incorporated into, or permanently affixed to the infrastructure. An article, material, or supply incorporated into an infrastructure project should not be considered to fall into multiple categories, but rather must meet the Buy America Preference Requirement for only the single category in which it is classified.

The Buy America Requirement applies to public infrastructure projects in the United States. For purposes of this guidance, applicants should consider whether the infrastructure project will serve a public function. Infrastructure projects should generally be considered “public” if the infrastructure is: publicly owned, privately owned but operated on behalf of the public, or is a place of public accommodation. Review the implementation guidance in OMB Memorandum OMB

[17] Excludes cement and cementitious materials, aggregates such as stone, sand, or gravel, or aggregate binding agents or additives.

Memorandum M-24-02 and consult with DOE if you are unsure if your project is subject to Buy America requirements.

All iron and steel, manufactured products, and construction materials used in the infrastructure project must be produced in the United States.

*Section *70917(c) Materials* are cement and cementitious materials; aggregates such as stone, sand, or gravel; or aggregate binding agents or additives as provided in section 70917(c) of BABA. Section 70917 (c) materials are excluded from Construction materials. Asphalt concrete pavement mixes are typically composed of asphalt cement (a binding agent) and aggregates such as stone, sand, and gravel. Accordingly, asphalt is also excluded from the definition of Construction materials.

Section 70917(c) materials, on their own, are not manufactured products. Further, Section 70917(c) materials should not be considered manufactured products when they are used at or combined proximate to the work site—such as is the case with wet concrete or hot mix asphalt brought to the work site for incorporation. However, certain Section 70917(c) materials (such as stone, sand, and gravel) may be used to produce a manufactured product, such as is precast concrete. Precast concrete is made of components, is processed into a specific shape or form, and is in such state when brought to the work site. Furthermore, wet concrete should not be considered a manufactured product if not dried or set prior to reaching the work site.

Further clarification is provided in 2 CFR Part 184 on the circumstances under which a determination is made that Section 70917(c) materials should be treated as components of a manufactured product. That determination is based on consideration of: (i) the revised definition of the “manufactured products” at 2 CFR 184.3; (ii) a new definition of “section 70917(c) materials” at 2 CFR 184.3; (iii) new instructions at 2 CFR 184.4(e) on how and when to categorize articles, materials, and supplies; and (iv) new instructions at 2 CFR 184.4(f) on how to apply the Buy America preference by category.

The recipient is responsible for flowing the Buy America Requirements down to all subawards, contracts,, subcontracts and purchase orders for work performed under the proposed infrastructure project, including to for-profit entities when they for-profit entity is a subrecipient or subawardee. except where the prime recipient is a for-profit entity.

Recipients must certify or provide equivalent documentation for proof of compliance that a good faith effort was made to solicit bids for domestic products used in the infrastructure project under this award.

Recipients must also maintain certifications or equivalent documentation for proof of compliance that those articles, materials, and supplies that are consumed in, incorporated into,

affixed to, or otherwise used in the infrastructure project, not covered by an approved waiver or an exemption provided in 2 CFR 184.8, are produced in the United States. The certification or proof of compliance must be provided by the suppliers or manufacturers of the iron, steel, manufactured products and construction materials and flow up from all subawardees, contractors and vendors to the recipient. Recipients must keep these certifications with the award/project files and be able to produce them upon request from DOE, auditors or Office of Inspector General.

C. DOE Submission Requirements for Full Application

Within the first two pages of the workplace or project description, applicants must provide a short statement on whether the project will involve the construction, alteration, maintenance and/or repair of infrastructure in the United States. The ultimate determination about whether a project includes infrastructure remains with DOE, but the applicant's statement will assist project planning and integration of the Buy America Requirement, wwhich may impact the project's proposed budget and/or schedule.

D. Waivers

In limited circumstances, DOE may waive the application of the Buy America Requirement in an award where DOE determines that:

> (1) applying the Buy America requirements would be inconsistent with the public interest (Public Interest);
>
> (2) the types of iron, steel, manufactured products, or construction materials are not produced in the United States in sufficient and reasonably available quantities or of a satisfactory quality (Non-Availability); or
>
> (3) the inclusion of iron, steel, manufactured products, or construction materials produced in the United States will increase the cost of the overall project by more than 25 percent (Unreasonable Cost).

DOE will only process waiver requests after an award has been made but prior to any purchase of items the recipient is seeking to waive, and for which the requests have been submitted in accordance with the term and conditions of the award. Waiver requests must be reviewed by DOE and the Office of Management and Budget's Made in America Office and are subject to a public comment period of no less than 15 calendar days.

DOE or OMB may request additional information for consideration of the wavier. DOE may reject or grant waivers in whole or in part depending on its review, analysis, and/or feedback from OMB or the public. DOEs final determination regarding approval or rejection of the waiver request may not be appealed by a recipient.

Requests to waive the Buy America Requirement must include the following:

- Waiver Type (Public Interest, Non-Availability, or Unreasonable Cost)
- Recipient name and Unique Entity Identifier (UEI)
- Award Information (Federal Award Identification Number, Assistance Listing Number)
- A brief descriptin of the project, its location, and the specific infrastructure involved;
- Total estimated project cost, with estimated federal share and recipient cost share breakdowns;
- Total estimated infrastructure costs, with estimated federal share and recipient cost share breakdowns;
- List and description of iron or steel item(s), manufactured goods, and/or construction material(s) the applicant or recipient seeks to waive from the Buy America Requirement, including name, cost, quantity(ies), country(ies) of origin , and relevant Product Service Codes (PSC) and North American Industry Classification System (NAICS) code for each.
- A detailed justification as to how the non-domestic item(s) is/are essential to the project;
- A certification that the recipient made a good faith effort to solicit bids for domestic products supported by terms included in requests for proposals, contracts, and non-proprietary communications with potential suppliers;
- A justification statement-based on one of the applicable justifications outlined above-as to why the listed items cannot be procured domestically, including the due diligence performed (e.g.g, market research, industry outreach, cost analysis, cost-benefit analysis) by the recipient to attempt to avoid the need for a waiver. This justification may cite, if applicable, the absence of any Buy-America-compliant bides received for domestic products in response to a solicitation;
- A description of the market research conducted that includes who conducted the market research, when it was conducted, sources that were used, and the methods used to conduct the research; and
- Anticipated impact if no waiver is issued

Appendix H – Statement of Project Objectives Template

REMINDER: APPLICANTS SHOULD DOUBLE SPACE THE STATEMENT OF PROJECT OBJECTIVES (INCLUDING THE REQUIRED SECTIONS INDICATED BELOW) IN ACCORDANCE WITH THE FORM AND CONTENT REQUIREMENTS IN SECTION IV, "APPLICATION AND SUBMISSION INFORMATION" AND REMOVE THIS BLOCK PRIOR TO SUBMISSION.

STATEMENT OF PROJECT OBJECTIVES

Title of Project

(Insert the title of the work to be performed. Be concise and descriptive)

This should be a standalone document that states the work to be conducted and should not include any proprietary/confidential information.

A. OBJECTIVES

Include one paragraph on the overall objective(s) of the work. Note: if the project will be performed in phases, include specific objective(s) for each phase of the work.

B. SCOPE OF WORK

This section should not exceed one-half page and should summarize the effort and approach to achieve the objective(s) of the work. Note: if the project will be performed in phases, includes specific scope statement(s) for each phase.

C. TASKS TO BE PERFORMED

This section provides a brief summary of the planned approach to this project. Tasks/subtasks, concisely written, should be provided in a logical sequence and should be divided into the phases of the project, as appropriate. In writing the Statement of Project Objectives (SOPO), avoid 1) the use of proper nouns to minimize SOPO modifications in the event of changes to the project team, facilities, etc.; 2) figures and equations; 3) references to other documents and publications; and 4) details about past work and discussion of technical background (which should be covered elsewhere in the application narrative). Tasks should be organized by Budget Period (BP), if applicable, with clear quantitative and qualitative success metrics that will be evaluated and met prior to continuing into the subsequent BP.

Task 1.0 - Project Management and Planning (REQUIRED; APPLICANT INSERT THIS TASK)

Subtask 1.1 – Project Management Plan (REQUIRED; APPLICANT INSERT THE LANGUAGE PROVIDED BELOW IN QUOTES. SEE THE "PROJECT MANAGEMENT PLAN TEMPLATE" APPENDIX FOR FORMAT.)

“The Recipient shall manage and direct the project in accordance with a Project Management Plan to meet all technical, schedule and budget objectives and requirements. The Recipient will coordinate activities in order to effectively accomplish the work. The Recipient will ensure that project plans, results, and decisions are appropriately documented and project reporting and briefing requirements are satisfied.

The Recipient shall update the Project Management Plan 30 days after award and as necessary throughout the project to accurately reflect the current status of the project. Examples of when it may be appropriate to update the Project Management Plan include: (a) project management policy and procedural changes; (b) changes to the technical, cost, and/or schedule baseline for the project; (c) significant changes in scope, methods, or approaches; or (d) as otherwise required to ensure that the plan is the appropriate governing document for the work required to accomplish the project objectives.

Management of project risks will occur in accordance with the risk management methodology delineated in the Project Management Plan in order to identify, assess, monitor and mitigate technical uncertainties as well as schedule, budgetary and environmental risks associated with all aspects of the project. The results and status of the risk management process will be presented during project reviews and in quarterly progress reports with emphasis placed on the medium- and high-risk items.”

Subtask 1.2 – Technology Maturation Plan (REQUIRED; APPLICANT INSERT THE LANGUAGE PROVIDED BELOW IN QUOTES. REFERENCE THE “TECHNOLOGY MATURATION PLAN” APPENDIX FOR FORMAT.) (Not applicable to AOI-4A)

“The Recipient shall develop a Technology Maturation Plan (TMP) that describes the current technology readiness level (TRL) of the proposed technology/technologies, relates the proposed project work to maturation of the proposed technology, describes the expected TRL at the end of the project, and describes any known post-project research and development necessary to further mature the technology. The initial TMP is due 90 days after award and should be updated as needed throughout the project period of performance. A final TMP should be submitted within 90 days of completion of the project.”

APPLICANT continue with tasks/sub-tasks as necessary. If the project is structured in Phases, clearly delineate which tasks/subtasks are in each Phase.

Task 2.0 - Community Benefits Plan
The Recipient shall (1) advance the diversity, equity, inclusion, and accessibility (DEIA); (2) contribute to energy equality; and (3) invest in America’s workforce. The

Recipient shall carry out activities in accordance with the Community Benefits Plan (CBP) that advances the three objectives above. The Recipient shall complete at least one Specific, Measurable, Attainable, Realistic, and Timely (SMART) milestone per budget period to measure progress. The Recipient shall report on CBP activities and milestones during the award and as part of the Final Report.

BP 1
Task 3.0 - (Title)
Task descriptions should include a concise description of the work to be conducted for each task. If the task includes subtasks, provide a general description of how each subtask is related to the overall scope of the task.

Subtask 3.1 - (Title)
Subtask descriptions should include a concise description of the work to be conducted for each subtask.

Subtask 3.2 - (Title)

Budget Period Continuation
In accordance with the "Continuation Application and Funding" article in this Cooperative Agreement, DOE funding is not authorized beyond Budget Period 1 without the written approval of the Contracting Officer. DOE's decision whether to authorize funding for Budget Period 2 is contingent on (1) availability of funds appropriated by Congress for the purpose of this program; (2) the availability of future-year budget authority; (3) substantial progress towards meeting the objectives of your approved application, including satisfactory completion of applicable success criteria; (4) submittal of required reports; and (5) compliance with the terms and conditions of the award."
BP 1 Success Criteria: Specific success criteria should be inserted here for BP 1.

Continue with additional BPs, tasks, subtasks, and success criteria as necessary for the entire project.

D. DELIVERABLES (Required: Applicant insert the Language provided below in quotes and continue to complete.)

The periodic and final reports shall be submitted in accordance with the "Federal Assistance Reporting Checklist" and the instructions accompanying the checklist. In addition to the reports specified in the "Federal Assistance Reporting Checklist", the Recipient must provide the following to the NETL Project Manager (identified in Block 15 of the Assistance Agreement as the Program Manager)**."**

Task / Subtask Number	Deliverable Title	Due Date
1.1	Project Management Plan	Update due 30 days after award. Revisions to the PMP shall be submitted as requested by the NETL Project Manager.
1.2	Technology Maturation Plan (TMP) (Not required for AOI-4A)	The initial TMP is due 90 days after award. Updates to the TMP shall be submitted, as needed, throughout the project period of performance. A final TMP is due within 90 days of project completion.
X	Techno-Economic Analysis (TEA) (Not required for AOI-4A)	Due 120 days after award, and should be updated with the experimental data acquired throughout the project period of performance. The Final TEA is due 90 days prior to project completion.
X	Life Cycle Analysis (LCA) (Not required for AOI-4A)	Due 120 days after award, and should be updated with the experimental data acquired throughout the project period of performance. The Final LCA is due 90 days prior to project completion.
X	(AOI-3 only) Summary of the Process Model	Due 120 days after award, and should be updated with the experimental data acquired throughout the project period of performance. The Final summary of the process model is due 90 days prior to project completion.
X	State Point Data Table (Not required for AOI-4A)	Due 90 days prior to project completion.
X	Technology EH&S Risk Assessment (Not required for AOI-4A)	Due 90 days prior to project completion.
X	(AOI-1 only) Environmental Justice Questionnaire	Due 90 days prior to project completion
X	Technology Gap Analysis (Not required for AOI-4A)	Due 90 days prior to project completion
X	(AOI-3 only) Risk Management Plan	Due 120 days after award. Updates to the Risk Management Plan shall be submitted, throughout the project period of performance as risks are being retired. The Final Risk Management Plan is due 90 days prior to project completion.
X	(AOI-3H-a and AOI-3H-b only) Business Case Analysis	Due 90 days prior to project completion
X	(AOI-4A only) Final Schedule of Pre-FEED Study Deliverables (as listed in FOA Appendix D, Section II)	Due 30 days after award.

X	(AOI-4A only) Pre-FEED Study Deliverables (as listed in FOA Appendix D, Section II)	Due as specified in the Final Schedule of Pre-FEED Study Deliverables.

APPLICANT continue to identify deliverables (other than those identified on the "Federal Assistance Reporting Checklist") that will be delivered using the format provided in the table above. Ensure the delivery date to NETL is also identified. For examples: Delivery to NETL X months after completion of task/subtask X.

NOTE: If the application is selected for award, DOE may require the Recipient to include additional deliverables, provided that such deliverables are consistent with the budget, schedule, and scope of the project.

E. BRIEFINGS/TECHNICAL PRESENTATIONS (Required: Applicant insert the language provided below in quotes and continue to complete.)

"The Recipient shall prepare detailed briefings for presentation to the NETL Project Manager at their facility located in Pittsburgh, PA, Morgantown, WV, Albany, OR, or via WebEx. The Recipient shall make a presentation to the NETL Project Manager at a project kick-off meeting held within ninety (90) days of the project start date. At a minimum, annual briefings shall also be given by the Recipient to explain the plans, progress, and results of the technical effort and a final project briefing at the close of the project shall also be given."

At the Applicant's discretion, other briefings/presentations may be added to Section E of the SOPO.

NOTE: If the application is selected for award, DOE may require the Recipient to include additional briefings/presentations, provided that such briefings/presentations are consistent with the budget, schedule, and scope of the project.

Appendix I – Project Management Plan Template

REMINDER: APPLICANTS SHOULD DOUBLE SPACE THE PROJECT MANAGEMENT PLAN IN ACCORDANCE WITH THE FORM AND CONTENT REQUIREMENTS IN SECTION IV, "APPLICATION AND SUBMISSION INFORMATION AND REMOVE THIS BLOCK PRIOR TO SUBMISSION.

The Applicant's Project Management Plan (PMP) is an approved document that defines how the Applicant will execute, monitor, and control the project to accomplish the objectives. The specific contents, level of detail, and inclusion of subsidiary planning documents are tailored according to the needs of the project. Consequently, every PMP will be different based on the risk, visibility, and/or complexity of the project and the Recipient's established processes, procedures, and systems.

Title Page:

PROJECT MANAGEMENT PLAN

{Insert Project Title}

{Date Prepared}

SUBMITTED BY
{Organization Name}
{Organization Address}
{City, State, Zip Code}

PRINCIPAL INVESTIGATOR
{Name}
{Phone Number}
{E-mail}

SUBMITTED TO
U.S. Department of Energy
National Energy Technology Laboratory

This plan should be formatted to include the following sections with each section to include the information as described below:

A. Executive Summary:

Provide a description of the project that includes the objective, project goals, and expected results. For purposes of the application, this information is included in the

Project Narrative and should be simply copied to this document for completeness, so that the Project Management Plan is a stand-alone document.

B. Project Organization and Structure:

Provide the following information in this section:

- Organizational Chart(s): Include a complete project organizational chart and sub-organization charts (if applicable), accompanied by a discussion of how the organizational structure will facilitate the performance of the Tasks and achievement of the objectives described in the SOPO within the time frame specified in the application.
- Roles and Responsibilities of Participants: Provide a discussion of key project team members, and the capacity in which each team member will assist in achieving the overall objective(s) of the proposed project. For multi-organizational or multi-investigator projects, describe the roles to be performed by each participant/investigator within the context of the Task/subtask structure contained in the SOPO. Include descriptions of any business agreements or intellectual property issues between the applicant and other members of the project team, and how these agreements will be integrated and managed.
- Decision-making and Communication Strategy: Provide a discussion of how communication and decision-making will occur within the context of the organizational structure, with particular emphasis on scientific/technical direction and mechanisms for controlling project scope, cost, and schedule. Include a discussion of how the project team will communicate with DOE and external stakeholders during the performance of the project.
- Management Capabilities: Provide information relevant to the capabilities and experience of the PI and key project team members in managing technical projects of similar nature and complexity. If applicable, include examples that demonstrate the ability to successfully meet research objectives within scope, budget and schedule.

C. Risk Management Plan:

Provide a summary description of the proposed approach to identify, analyze, and respond to perceived risks associated with the proposed project. Project risk events are uncertain future events that, if realized, impact the success of the project. Risk is inherent to all projects regardless of complexity, cost, or visibility. An effective Risk Management Plan will identify perceived risks and explain mitigation strategies for each risk. At a minimum, the Risk Management Plan shall include the initial identification of significant financial, cost/schedule, technical/scope, management, planning and oversight, ES&H, external factors, and management issues that have the potential to impede project progress and strategies to minimize impacts from those issues.

The following table format is provided but is not required:

Perceived Risks and Mitigation Strategies

Perceived Risk	Risk Rating			Mitigation/Response Strategy
	Probability (Low, Med, High)	Impact	Overall	
Financial Risks:				
Cost/Schedule Risks:				
Technical/Scope Risks:				
Management, Planning, and Oversight Risks:				
ES&H Risks:				
External Factor Risks:				

D. Milestone Log:

Provide milestones for each budget period of the project. Each milestone should be linked to a specific Task or Subtask and include a title, planned completion date, and a description of the method/process/measure used to verify completion. Milestones should be quantitative and show progress toward budget period and/or project goals. Conversely, periodic, mandatory progress reports are not considered to be Milestones.

Milestones are presumed to lie on the critical path of the project, i.e., unless all milestones are achieved, the Objectives as defined in the SOPO cannot be met completely. Applicants must provide at least two milestones per year throughout the course of the project.

Milestone Format

Task/ Subtask	Milestone Title & Description	Planned Completion Date	Verification method

[Note: During project performance, the Recipient will report the Milestone Status as part of the required quarterly progress report as prescribed under the Federal Assistance Reporting Checklist. The Milestone Status will present actual performance in comparison with Planned Milestones, and include:

(1) the actual status and progress of the project,

(2) specific progress made toward achieving the project's milestones, and,

(3) any proposed changes in the project's schedule required to complete milestones.]

E. Costing Profile:

Provide a table (the Spend Plan) that projects the expenditures of government funds by fiscal year for each project team member.

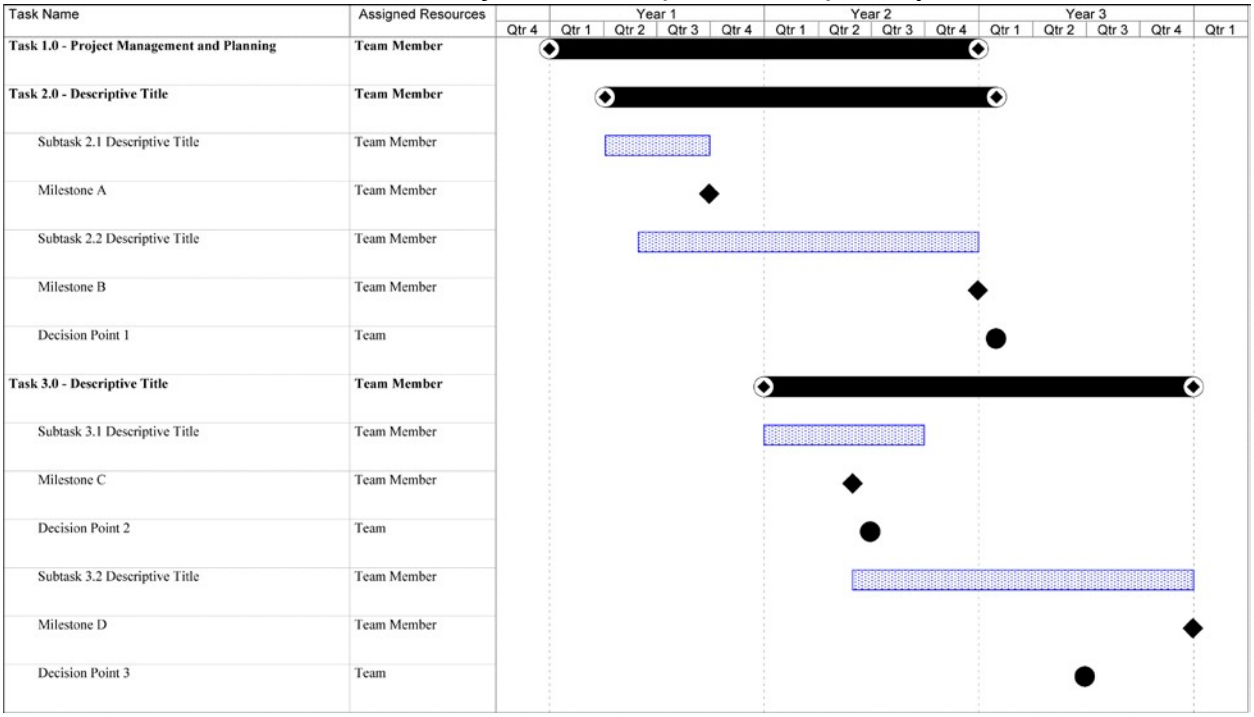
Spend Plan by Fiscal Year Format

	FY 20XX		**FY 20XX**		**FY 20XX**		**FY 20XX**		**Total**	
	DOE Funds	**Cost Share**	**DOE Funds**	**Cost Share**	**DOE Funds**	**Cost Share**	**DOE Funds**	**Cost Share**	**DOE Funds**	**Cost Share**
Applicant										
Subrecipient A, if proposed										
Subrecipient B, if proposed										
FFRDC/NL, if proposed										
Total ($)										
Total Cost Share %										

F. Project Timeline:

Provide a timeline of the project (similar to a Gantt chart) broken down by each task and subtask, as described in the Statement of Project Objectives. The timeline should include for each task, a start date, and end date. The timeline should show interdependencies between tasks and include the milestones that are identified in the Milestone Log (Section C).

Project Timeline (Gantt Chart) Example



G. Success Criteria:

Success criteria are used by the DOE to determine if specific goals and objectives were met at the end of budget period(s), go/no-go decision points, and/or project completion. The success criteria should be objective and stated in terms of specific, measurable, and repeatable data. Usually, the success criteria pertain to desirable outcomes, results, and observations from the project.

[Note: As the first task in the Statement of Project Objectives, successful applicants will revise the version of the Project Management Plan that is submitted with their applications by including details from the negotiation process. This Project Management Plan will be updated by the Recipient as the project progresses, and the Recipient must use this plan to report scope, schedule, and budget variances.]

Appendix J – Data Management Plan

A Data Management Plan ("DMP") explains how data generated in the course of the research or work performed under an assistance award will be shared and preserved or, when justified, explains why data sharing or preservation is not possible or scientifically appropriate.

DMP Requirements

In order for a DMP to be considered acceptable, the DMP must address the following:

At a minimum, the DMP must describe how data sharing and preservation will enable validation of the results from the proposed work, or how results could be validated if data are not shared or preserved.

The DMP must provide a plan for making all research data displayed in publications resulting from the proposed work digitally accessible at the time of publication. This includes data that are displayed in charts, figures, images, etc. In addition, the underlying digital research data used to generate the displayed data should be made as accessible as possible in accordance with the principles stated above. This requirement could be met by including the data as supplementary information to the published article, or through other means. The published article should indicate how these data can be accessed.

The DMP should consult and reference available information about data management resources to be used in the course of the proposed work. In particular, a DMP that explicitly or implicitly commits data management resources at a facility beyond what is conventionally made available to approved users should be accompanied by written approval from that facility. In determining the resources available for data management at DOE User Facilities, researchers should consult the published description of data management resources and practices at that facility and reference it in the DMP. Information about other DOE facilities can be found in the additional guidance from the sponsoring program.

The DMP must protect confidentiality, personal privacy, Personally Identifiable Information, and U.S. national, homeland, and economic security; recognize proprietary interests, business confidential information, and intellectual property rights; avoid significant negative impact on innovation, and U.S. competitiveness; and otherwise be consistent with all laws (i.e., export control laws), and DOE regulations, orders, and policies.

Data Determination for a DMP

The Principal Investigator should determine which data should be the subject of the DMP and, in the DMP, propose which data should be shared and/or preserved in accordance with the DMP Requirements noted above.

For data that will be generated through the course of the proposed work, the Principal Investigator should indicate what types of data should be protected from immediate public disclosure by DOE (referred to as "protected data") and what types of data that DOE should be able to release immediately. Similarly, for data developed outside of the proposed work at private expense that will be used in the course of the proposed work, the Principal Investigator should indicate whether that type of data will be subject to public release or kept confidential (referred to as "limited rights data"). Any use of limited rights data or labeling of data as "protected data" must be consistent with the DMP Requirements noted above.

Suggested Elements for a DMP

The following list of elements for a DMP provides suggestions regarding the data management planning process and the structure of the DMP:

Data Types and Sources: A brief, high-level description of the data to be generated or used through the course of the proposed work and which of these are considered digital research data necessary to validate the research findings or results.

Content and Format: A statement of plans for data and metadata content and format including, where applicable, a description of documentation plans, annotation of relevant software, and the rationale for the selection of appropriate standards. Existing, accepted community standards should be used where possible. Where community standards are missing or inadequate, the DMP could propose alternate strategies for facilitating sharing, and should advise the sponsoring program of any need to develop or generalize standards.

Sharing and Preservation: A description of the plans for data sharing and preservation. This should include, when appropriate: the anticipated means for sharing and the rationale for any restrictions on who may access the data and under what conditions; a timeline for sharing and preservation that addresses both the minimum length of time the data will be available and any anticipated delay to data access after research findings are published; any special requirements for data sharing, for example, proprietary software needed to access or interpret data, applicable policies, provisions, and licenses for re-use and re-distribution, and for the production of derivatives, including guidance for how data and data products should be cited; any resources and capabilities (equipment, connections, systems, software, expertise, etc.) requested in the research proposal that are needed to

meet the stated goals for sharing and preservation (this could reference the relevant section of the associated research proposal and budget request); and whether/where the data will be preserved after direct project funding ends and any plans for the transfer of responsibilities for sharing and preservation. A description of how the recipient intends to make the results of any resulting DOE-funded work available to the public, including the relevant technical community.

Protection: A statement of plans, where appropriate and necessary, to protect confidentiality, personal privacy, Personally Identifiable Information, and U.S. national, homeland, and economic security; recognize proprietary interests, business confidential information, and intellectual property rights; and avoid significant negative impact on innovation, and U.S. competitiveness.

Rationale: A discussion of the rationale or justification for the proposed data management plan including, for example, the potential impact of the data within the immediate field and in other fields, and any broader societal impact.

Additional Guidance

In determining which data should be shared and preserved, researchers must consider the data needed to validate research findings as described in the Requirements and are encouraged to consider the potential benefits of their data to their own fields of research, fields other than their own, and society at large.

DMPs should reflect relevant standards and community best practices and make use of community accepted repositories whenever practicable.

Costs associated with the scope of work and resources articulated in a DMP may be included in the proposed research budget as permitted by the applicable cost principles.

To improve the discoverability of and attribution for datasets created and used in the course of research, DOE encourages the citation of publicly available datasets within the reference section of publications, and the identification of datasets with persistent identifiers such as Digital Object Identifiers (DOIs). In most cases, DOE can provide DOIs free of charge for data resulting from DOE-funded research through its Office of Scientific and Technical Information (OSTI) DataID Service.

Definitions

Data Preservation: Data preservation means providing for the usability of data beyond the lifetime of the research activity that generated them.

Data Sharing: Data sharing means making data available to people other than those who have generated them. Examples of data sharing range from bilateral communications with colleagues, to providing free, unrestricted access to anyone through, for example, a web-based platform.

Digital Research Data: The term digital data encompasses a wide variety of information stored in digital form including: experimental, observational, and simulation data; codes, software and algorithms; text; numeric information; images; video; audio; and associated metadata. It also encompasses information in a variety of different forms including raw, processed, and analyzed data, published and archived data.

Research Data: The recorded factual material commonly accepted in the scientific community as necessary to validate research findings, but not any of the following: preliminary analyses, drafts of scientific papers, plans for future research, peer reviews, or communications with colleagues. This 'recorded' material excludes physical objects (e.g., laboratory samples). Research data also do not include:

(A) Trade secrets, commercial information, materials necessary to be held confidential by a researcher until they are published, or similar information which is protected under law; and

(B) Personnel and medical information and similar information the disclosure of which would constitute a clearly unwarranted invasion of personal privacy, such as information that could be used to identify a particular person in a research study."

Validate: In the context of DMPs, validate means to support, corroborate, verify, or otherwise determine the legitimacy of the research findings. Validation of research findings could be accomplished by reproducing the original experiment or analyses; comparing and contrasting the results against those of a new experiment or analyses; or by some other means.

Appendix K – Technology Maturation Plan

TECHNOLOGY MATURATION PLAN
for {insert project title}
{Date Prepared}

SUBMITTED UNDER FUNDING OPPORTUNITY ANNOUNCEMENT

DE-FOA-#######

SUBMITTED BY

{Organization Name}
{Organization Address}
{City, State, Zip Code}

PRINCIPAL INVESTIGATOR

{Name}
{Phone Number}
{E-mail}

SUBMITTED TO

U.S. Department of Energy
National Energy Technology Laboratory

A technology maturation plan (TMP) is a planning tool that summarizes the necessary research and development (R&D) steps to advance the maturation of a specified technology to a targeted technology readiness level (TRL) and defines the key performance metrics that will be used to determine if the targeted TRL has been successfully achieved. A TMP also documents the current TRL of the specified technology, defines the ultimate commercial application of the technology, and conceptualizes a future commercialization pathway in terms of additional R&D, resources and schedule. A TMP is a high-level summary document. It is not a collection of detailed test plans. Successful applicants will be required to prepare a TMP that describes the current technology readiness level (TRL) of the proposed technology/technologies, relates the proposed project work to maturation of the proposed technology, describes the expected TRL at the end of the project, and describes any known post-project research and development necessary to further mature the technology.

The National Energy Technology Laboratory (NETL) uses TMPs to enhance its stewardship of R&D project portfolios and improve the value of the technologies it develops. TMPs help NETL to:

- ensure that research questions are resolved in the least expensive and least risky R&D setting (i.e., scale, degree of integration, environment, fidelity)
- focus technology development on the performance metrics that are most important for technical and economic success (at component and system levels)
- identify R&D gaps and critical components that are lagging in maturity
- ensure that R&D projects address what is required for integration into higher-level systems
- make informed decisions at critical stages of research (e.g., moving a technology from a laboratory project to a larger-scale pilot project)
- improve the balance of project portfolios in terms of technology types, pathways, TRLs, redundancy, etc., to mitigate risks and increase the likelihood of R&D success, and
- forecast the cost and duration of technology development through demonstration and commercialization.

The below template should be used to complete a TMP. Instructions, shown in italics, should be deleted/replaced in the completed TMP. Section 3 is provided solely for reference but should be retained as-is in the completed TMP.

For **AOI-3H-a and AOI-3H-b**, the TMP should show how the technology will both increase in scale and decrease in cost through 2035. The TMP should identify and propose plausible pathways on how the proposed NG power plant **(AOI-3H-a)** or clean hydrogen production plant **(AOI-3H-b)** will achieve overall net zero carbon emissions by 2035 through implementing the proposed advanced carbon capture system in combination with other approaches including, but not limited to, increased process energy efficiency, utilization of low or zero carbon fuel, or other carbon dioxide removal (CDR) technologies (e.g., direct air capture (DAC)). However, the pre-FEED study should not include work to design these technology options. TMP should also include a sensitivity analysis as a function of technology options to achieve overall net zero carbon emissions. Objective variables should include cost of capture **(AOI-3H-a and AOI-3H-b)**, cost of electricity **(AOI-3H-a)**, and cost of clean hydrogen production **(AOI-3H-b)**. Also included in this effort should be any data gaps that need to be addressed through R&D.

1.0 INTRODUCTION

1.1 Purpose of the Project

Provide a brief summary of the project's objectives as related to maturation of the proposed technology.

1.2 Technology Readiness Assessment System

Technology maturation is quantified by a performing a technology readiness assessment (TRA) on the specified technology system.

- Identify the specified "TRA System" and describe all the critical components and/or subsystems that comprise it. See "TRA System" definition under Section 3.1.
- State whether the current project will test: (1) the total, integrated TRA System, or (2) one or more critical subsystems or components of the TRA System. If the latter, identify which critical subsystems and/or components will be tested.

1.3 Commercial Application

Provide a one-paragraph description of the targeted commercial application(s) of the TRA System.

2.0 MATURATION OF THE TRA SYSTEM

2.1 Beginning Technology Readiness Level (TRL) of the TRA System

Briefly summarize the prior research that matured the technology to its current state.

Using the Technology Readiness Levels (TRL) descriptions in Sections 3.2 and 3.3, specify the current (i.e., pre-project) TRL of the TRA System. To attain a certain TRL, all aspects of the associated TRL description must be met.

Justify the specified TRL by explaining how all the required TRL aspects have been achieved.

2.2 Proposed Research to Mature the TRA System

Identify the TRL that the project plans to attain.

- Note that the targeted TRL could be the same as the beginning TRL if the project is aimed at making only incremental progress toward achieving the next TRL.
- If the project proposes to advance the TRL by more than one level, explain if that will be accomplished in stages (i.e., first one TRL, then the next) or by skipping a TRL. If the latter, explain how any increased technical, cost and schedule risks associated with skipping a TRL will be mitigated.

Identify each of the key performance attributes that will be assessed during the research along with the corresponding, quantifiable performance requirements that

must be achieved to attain the targeted TRL(s). Explain how the key performance attributes were selected and how the corresponding requirements were determined. Be as specific as practical on any supporting technical/economic assessments (see Section 3.4 for NETL's Systems Analysis Best Practices). As a general principle, all key performance requirements that may be appropriately tested at a particular TRL must be substantially met, thereby supporting the feasibility of commercial success/goal achievement, prior to proceeding to the subsequent TRL.

Briefly summarize the proposed research steps and how they will mature the TRA System to the targeted TRL(s).

2.3 Potential Post-Project Maturation and Commercialization of the TRA System

Assuming the project successfully attains the targeted TRL(s), describe what additional (post-project) work would be required to mature the TRA System to the next TRL. Identify the key performance requirements and goals/measures that would need to be achieved. If possible, provide rough estimates of the cost and duration of the research required to attain the next TRL.

Describe your organization's potential role in a commercialization strategy for the TRA system.

3.0 REFERENCE MATERIAL

3.1 Definition of TRA System

NETL's interpretation (Section 3.2) of the DOE TRL definitions (Section 3.3) is based on a view of technology maturation in which "components" are integrated into a "system" that is being assessed for its technology readiness. To clearly and consistently apply the DOE TRL definitions, one must first precisely identify what "system" is being assessed, defined herein as the "Technology Readiness Assessment (TRA) System." Since most technologies can be viewed as subsystems within larger systems, multiple choices are available for defining the TRA System. However, note that the choice of the "level" of the TRA System affects how TRLs are assessed:

- A TRL 3 is achieved for the specified TRA System when analytical performance predictions for each of the TRA System's critical[18] components have been

[18] A component or subsystem of a TRA System is considered critical if it is new, novel, and necessary for the TRA System to meet its anticipated operational performance requirements or poses major cost, schedule, or performance risk during design or demonstration. Note that a component that is fully mature and non-critical for an established application or operational environment may be considered critical if it is incorporated into a new application or operational environment.

validated in separate experiments (i.e., without integration across components). Accordingly, the table in Section 3.2 shows the required scope of TRL 3 as "single component" and the required integration of TRL 3 as "none."

- A TRL 4 or 5 is achieved for a given TRA System when the targeted performance requirements for each of its critical, multi-component subsystems (or the entire TRA system) have been validated in a laboratory environment (TRL 4) or relevant environment (TRL 5) with integration of some or all components.
- Achieving TRLs 6 to 9 requires testing of the entire, fully integrated, TRL system.

To further clarify, consider, for example, a fuel cell stack. Its critical components are multiple, identical fuel cells. In turn, the critical components of each fuel cell are an anode, cathode and electrolyte. If one wished to assess the technology readiness of the fuel cell stack, the TRA System would be defined as an integrated system of multiple fuel cell subsystems, and a TRL 6 could only be achieved by successfully testing an entire stack of integrated fuel cells. However, if one instead wished to assess the technology readiness of only the fuel cell, the TRA System would be defined as an integrated system of cathode, anode and electrolyte components, and a TRL 6 could be achieved by successfully testing just a single, integrated fuel cell. In both cases, achievement of TRL 6 could be claimed, but only in the context of the properly specified TRA System.

3.2 NETL Interpretations of DOE Technology Readiness Levels in the Context of Fossil Energy and Carbon Management R&D

<table>
<tr><th rowspan="2">TRL</th><th rowspan="2">DOE Definition</th><th colspan="6">Minimum Simultaneous Requirements to Achieve TRL
based on NETL Interpretation of DOE Definitions & Descriptions</th></tr>
<tr><th>Scope</th><th>Integration</th><th>Fidelity</th><th>Scale</th><th>Environment</th><th>Metrics</th></tr>
<tr><td>1</td><td>Basic principles observed and reported</td><td colspan="5" rowspan="2">Any experimentation is limited to discovery and validation of fundamental scientific principles. Formulation of the technology that applies the fundamental science is initiated in conceptual paper studies but experiments on the applied technology have not begun.</td><td>NA</td></tr>
<tr><td>2</td><td>Technology concept and/or applications formulated</td><td rowspan="9">Project-specific TMPs should define cost and/or performance metrics for relevant TRLs. To attain a given TRL, the technology must achieve the metrics for that TRL (or show a likely potential to do so).</td></tr>
<tr><td>3</td><td>Analytical and experimental critical function and/or characteristic proof of concept</td><td>Single Component</td><td>None</td><td>Low (ad-hoc hardware)</td><td rowspan="2">Lab</td><td rowspan="2">Lab (simulated conditions)</td></tr>
<tr><td>4</td><td>Component and/or system validation in laboratory environment</td><td rowspan="2">Total system or multi-component subsystem</td><td rowspan="2">Integration of some or all components</td></tr>
<tr><td>5</td><td>Laboratory scale, similar system* validation in relevant environment</td><td>High (nearly a prototype)</td><td rowspan="3">Relevant (regulated expected conditions)</td></tr>
<tr><td>6</td><td>Engineering/pilot-scale, similar (prototypical) system validation in relevant environment</td><td rowspan="4">Total system

(The total system is equivalent to the “TRA System,” which is the system or subsystem for which technology readiness is being assessed)</td><td rowspan="4">All components and subsystems integrated</td><td rowspan="2">Prototype</td><td>Small Pilot**</td></tr>
<tr><td>7</td><td>Full-scale, similar (prototypical) system demonstrated in relevant environment</td><td>Large Pilot or Full**</td></tr>
<tr><td>8</td><td>Actual system completed and qualified through test and demonstration. Technology has been proven to work in its final form and under expected conditions.</td><td>Actual system in final form</td><td rowspan="2">Full</td><td rowspan="2">Operational (unregulated actual conditions)</td></tr>
<tr><td>9</td><td>Actual operation of the technology in its final form, under the full range of conditions.</td><td>Commercially warranted</td><td>NA</td></tr>
<tr><td colspan="8">* The DOE TRL 5 description states that the “similar system” matches the final application in “almost all respects” and is “almost prototypical.” This table interprets the similar, but not fully prototypical, system as being either: a) the total system for which readiness is being evaluated, or b) a multi-component subsystem of the total system. This interpretation is supported by the DOE TRL 6 description which states that “TRL 6 begins true engineering development of the technology as an operational system.”
** DOE defines TRL 6 as a pilot-scale prototype and TRL 7 as a full-scale prototype. DOE defines TRLs 8 and 9 as involving “actual” systems at full scale. This table assumes that the scale of the TRL 7 full-scale prototype could be less than or equal to the scale of the TRL 8 full-scale actual system. At a minimum, the scale of the TRL 7 prototype must be sufficiently large to support subsequent testing of a TRL 8 full-scale actual system without the need for testing at an intervening scale.</td></tr>
</table>

3.3 Description of DOE Technology Readiness Levels

Source: U.S. Department of Energy, “Technology Readiness Assessment Guide”. Office of Management. 2011.

Relative Level of Technology Development	TRL	TRL Definition	Description
System Operations	9	Actual system operated over the full range of expected mission conditions.	The technology is in its final form and operated under the full range of operating mission conditions. Examples include using the actual system with the full range of wastes in hot operations.
System Commissioning	8	Actual system completed and qualified through test and demonstration.	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning. Supporting information includes operational procedures that are virtually complete. An Operational Readiness Review (ORR) has been successfully completed prior to the start of hot testing.
	7	Full-scale, similar (prototypical) system demonstrated in relevant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning (1). Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.

Relative Level of Technology Development	TRL	TRL Definition	Description
Technology Demonstration	6	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants.(1) Supporting information includes results from the engineering scale testing and analysis of the differences between the engineering scale, prototypical system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment.
Technology Development	5	Laboratory scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants (1) and actual waste (2). Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.
Technology Development	4	Component and/or system validation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small scale tests on actual waste (2). Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRL 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function.

Relative Level of Technology Development	TRL	TRL Definition	Description
Research to Prove Feasibility	3	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative tested with simulants.(1) Supporting information includes results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.
Basic Technology Research	2	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies. Supporting information includes publications or other references that outline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.
	1	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental work that consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.

[1] Simulants should match relevant chemical and physical properties.
[2] Testing with as wide a range of actual waste as practicable and consistent with waste availability, safety, ALARA, cost and project risk is highly desirable.

3.4 NETL Systems Analysis Best Practices

NETL has developed Systems Analysis Best Practices (SABP) as an accompaniment to the DOE Technology Readiness Level (TRL) definitions. The SABP serve as a guide for the Principal Investigator/researcher to inform on the level of systems and economic analysis rigor appropriate at each TRL.

System and economic analyses are an essential component of research and development (R&D). They are used to determine appropriate experimental conditions, inform R&D targets and technology maturation plans, assess R&D progress, and estimate the benefits of successful technology development in commercial applications.

Systems analysis is the analytic process used to evaluate the behavior and performance of processes, equipment, subsystems, and systems. Such analyses serve to characterize the relationships between independent (e.g., design parameters and configurations, material properties, etc.) and dependent variables (e.g., thermodynamic state points, output, etc.) through the creation of models representative of the envisioned process, equipment, subsystem, or system. These analyses are used to determine the important variables (i.e., performance attributes) and the associated targets (i.e., performance requirements) that must be achieved through R&D and testing to realize commercial and/or program goals.

The performance requirements are selected such that the equipment, subsystem, or system meets the envisioned objectives in the target commercial application. The target commercial application refers to one specific use for the advanced technology, at full commercial scale. A project may include more than one target commercial application. For example:

1. Technologies that reduce the cost of gasification may be useful for both liquid fuels and power production.
2. Technologies that may be useful to monitor CO_2 storage in more than one type of storage site.

The modeling and simulation effort may use one or more of a variety of tools, such as Excel, MATLAB, Aspen Plus, Aspen Plus Dynamics, Thermoflow, CHEMCAD, etc., depending upon suitability to the specific processes, the scope of the development effort, and the stage of development.

An integral part of systems analysis is economic analysis - the process of estimating and assigning costs to equipment, subsystems, and systems corresponding to models of and specifications for the commercial embodiment of the technology. Such analyses include the estimation of capital costs, as well as operating and maintenance costs. Component service life and corresponding replacement costs are often a crucial aspect of these analyses. See Performing a Techno-economic Analysis for Power Generation Plants, DOE/NETL-2015/1726, July 2015, for further guidance.

As a technology matures, the systems analyses are frequently updated, and are expected to increase in fidelity and complexity commensurate with the available technical understanding, experimental data, and overall level of effort (cost of R&D).

The results are used to inform the next stage of development and provide specific experimental and analysis success criteria (the performance requirements).

As a general principle, the performance requirements that may be appropriately tested at a particular TRL must be substantially met, thereby supporting the feasibility of commercial success/goal achievement, prior to proceeding to the subsequent TRL. Note that, as with the TRL descriptions, these SABP are "gate-in;" that is, prerequisites to achieving the associated TRL.

NETL supports a wide range of RD&D projects, from small, short-duration materials development and property characterization projects up to large-scale power plant demonstrations. The nature and complexity of the technology under development and the scope of the project must be taken into account when applying the SABP – they may not be strictly applicable as written to every project. For example, it is an unreasonable expectation for a project developing a sensor, or fuel cell cathode, or thermal boundary coating for a turbine airfoil to perform a full-scale power plant simulation to determine the performance requirements of the specific technology in the course of pursuing TRL 4. However, the project must explicitly tie the quantitative goals/objectives for the technology to referenced system studies as well as relevant industry and/or market requirements in such a manner that their pedigree is readily traceable. On the other hand, a project endeavoring to develop a full system concept incorporating novel components and process integration is expected to perform more robust, extensive analyses.

Descriptions of the SABP associated with each TRL are provided in the table below.

TRL	DOE Definition	Systems Analysis Best Practices
1	Basic principles observed and reported	Assessment: Perform an assessment of the core technology resulting in (qualitative) projected benefits of the technology, a summary of necessary R&D needed to develop it into the actual technology, and principles that support of the viability of the technology to achieve the projected benefits.
2	Technology concept and/or applications formulated	White Paper: A white paper describing the intended commercial application, the anticipated environment the actual technology will operate in, and the results from the initiation of a detailed analysis (that will at least qualitatively justify expenditure of resources versus the expected benefits and identify initial performance attributes).
3	Analytical and experimental critical function and/or characteristic proof of concept	Performance Model and Initial Cost Assessment: This performance model is a basic model of the technology concept, incorporating relevant process boundary conditions, that provides insight into critical performance attributes and serves to establish initial performance requirements. These may be empirically- or theoretically-based models represented in Excel or other suitable platforms. In addition, an initial assessment and determination of performance requirements related to cost is completed.

TRL	DOE Definition	Systems Analysis Best Practices
4	Component and/or system validation in laboratory environment	System Simulation and Economic Analysis: These models incorporate a performance model of the technology (may be a simple model as developed for TRL 3, or something more detailed – either should be validated against empirical data gathered in the laboratory) into a model of the intended commercial system (e.g., power plant). In addition, an economic analysis (e.g., cost-of-electricity) of the technology is performed, assessing the impact of capital costs, operating and maintenance costs, and life on the impact of the technology and its contributions to the viability of the overall system in a commercial environment. These analyses serve to assess the relative impact of known performance attributes (through sensitivity analyses) and refine performance requirements in the context of established higher-level technical and economic goals (e.g., programmatic or DOE R&D goals). These models are typically created in process simulation software (e.g., ASPEN Plus) or other suitable platforms. DOE maintains guidance on the execution of techno-economic analyses [1].
5	Laboratory scale, similar system* validation in relevant environment	System Simulation and Economic Analysis Refinement: A more detailed process model for the technology, validated against empirical data gathered in the laboratory, will be developed and incorporated into system simulations. This provides greater fidelity in the performance and cost estimation for the technology, facilitating updates to performance attributes and requirements (including updates to the economic analysis). This also allows greater evaluation of other process synergy claims (e.g., state-of-the-art technology is improved by the use of the new technology). Cost estimation should be either vendor-based or bottom-up costing approaches for novel equipment.
6	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	System Simulation and Economic Analysis Refinement: Performance and cost models are refined based upon relevant environment laboratory results, leading to updated performance attributes and requirements. Preliminary steady-state and dynamic (if appropriate for the technology) modeling of all critical process parameters (i.e., upper and lower operating limits) of the system prototype is completed. Cost estimation should be either vendor-based or bottom-up costing approaches for novel equipment. Key process equipment should be specified to the extent that allows for bottom-up estimating to support a feasibility study of the integrated system.
7	Full-scale, similar (prototypical) system demonstrated in relevant environment	System Simulation and Economic Analysis Refinement: Performance and cost models are refined based upon relevant environment and system prototype R&D results. The refined process, system and cost models are used to project updated system performance and cost to determine if the technology has the potential to meet the project goals. Performance attributes and requirements are updated as necessary. Steady-state and dynamic modeling all critical process parameters of the system prototype covering the anticipated full operation envelope (i.e., upper and lower operating limits) is completed. Cost models should be based on vendor quotes and traditional equipment estimates should be minimal.

TRL	DOE Definition	Systems Analysis Best Practices
8	Actual system completed and qualified through test and demonstration. Technology has been proven to work in its final form and under expected conditions.	System Simulation and Economic Analysis Validation: The technology/system process models are validated by operational data from the demonstration. Economic models are updated accordingly.
9	Actual operation of the technology in its final form, under the full range of conditions.	Commercial Use: Models are used for commercial scaling parameters.

Appendix L – R&D Community Benefits Plan Guidance

The DOE is committed to pushing the frontiers of science and engineering; catalyzing high-quality domestic clean energy jobs through research, development, demonstration, and deployment; and ensuring energy equity and energy justice[19] for disadvantaged communities. Therefore, and in accordance with the Administration's priority to empower workers and harness opportunities to create good union jobs as stated in EO 14008 (Executive Order on Tackling the Climate Crisis at Home and Abroad)[20], it is important to consider the impacts of the successful commercial deployment of any innovations resulting from this FOA on the current and future workforce.

The goal of the R&D Community Benefits Plan is to allow the application to illustrate engagement in critical thought about implications of how the proposed work will benefit the American people and lead to broadly shared prosperity, including for workers and disadvantaged communities[21]. The three sections of the R&D Community Benefits Plans are considered together because there may be significant overlap among audiences considered in workforce and disadvantaged communities.

Example DEIA, Energy Equity, and Workforce Plan Elements

Outlined below are examples of activities that applicants might consider when developing their R&D Community Benefits Plan. Applicants are not required to implement any of these specific examples and should propose activities that best fits their research goals, institutional environment, team composition, and other factors. Creativity is encouraged.

DEIA

DOE strongly encourages applicants to involve individuals and entities from disadvantaged communities. Tapping all of the available talent requires intentional approaches and yields broad benefits.

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[19] DOE defines energy justice as "the goal of achieving equity in both the social and economic participation in the energy system, which also remediating social, economic, and health burdens on those disproportionately harmed by the energy system" (Initiative for Energy Justice, 2019). Aligned with that document refers to this as, 'energy equity,' and is meant to encompass energy justice as well as DOE's efforts related to Justice40. https://www.energy.gov/justice/articles/how-energy-justice-presidential-initiatives-and-executive-orders-shape-equity-doe

[20] https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad

[21] See footnote 14 for guidance on the definition and tools to locate and identify disadvantaged communities.

Equity extends beyond diversity to equitable treatment. Equitable access to opportunity for members of the project team is paramount. This includes ensuring that all members of the team, including students, are paid a living wage, provided appropriate working conditions, and provided appropriate benefits. In the execution of their project plan, applicants are asked to describe efforts in diversity, equity, inclusion, and accessibility. In this context, efforts toward DEIA are defined as:[22]

1) the practice of including the many communities, identities, races, ethnicities, backgrounds, abilities, cultures, and beliefs of the American people,
2) the consistent and systematic fair, just, and impartial treatment of all individuals, including protecting workers rights and adhering to Equal Employment Opportunity laws,
3) the recognition, appreciation, and use of the talents and skills of employees of all backgrounds, and
4) the provision of accommodations so that all people, including people with disabilities, can fully and independently access facilities, information, and communication technology, programs, and services.

Successful plans will not only describe how the project team seeks to increase DEIA, but will describe the overall approaches to retention, engagement, professional development, and career advancement. Specifically, they will demonstrate clear approaches to ensure all team members' strengths are meaningfully leveraged and all members are provided opportunities and paths for career development, especially including paths for interns and trainees to secure permanent positions. Diversity should be considered at all levels of the project team, not just leveraging early career individuals to meet diversity goals.

DOE strongly encourages applicants to consider partnerships to promote DEIA, justice, and workforce participation. Minority Serving Institutions, Minority Business Enterprises, Minority Owned Businesses, Disability Owned Business, Women Owned Business, Native American-owned Businesses, Veteran Owned Businesses, or entities located in an underserved community that meet the eligibility requirements are encouraged to lead these partnerships as the prime applicant or participate on an application as a proposed partner to the prime applicant.

When crafting the DEIA section of the Plan, applicants should describe how they will act to promote each of the four DEIA efforts above into their investigation. It is important to note that diversity, equity, inclusion, and accessibility are four different but related concepts that should not be conflated. For instance, you can achieve diversity without equity; all four must be addressed. Applicants could discuss how the proposed investigation could contribute to training and developing a diverse

[22] https://www.whitehouse.gov/wp-content/uploads/2021/11/Strategic-Plan-to-Advance-Diversity-Equity-Inclusion-and-Accessibility-in-the-Federal-Workforce-11.23.21.pdf

scientific workforce. Applicants could describe the efforts they plan to take or will continue to take, to create an inclusive workplace, free from retaliation, harassment, and discrimination. Applicants could outline any barriers to creating an equitable and inclusive workplace and address the ways in which the team will work to overcome these barriers within the bounds of the specific research project. This plan could detail specific efforts to inform project team members in any capacity of their labor rights and rights under Equal Employment Opportunity laws, and their free and fair chances to join a union. Note that this inclusion of informing project team members is also incorporated into awards through the National Policy Assurances.

Equal treatment of workers, including students, is necessary but overcoming institutional bias requires intentionally reducing sometimes hidden barriers to equal opportunity. Applicants could consider measures like childcare, flexible schedules, paid parental leave, pay transparency, and other supports to ensure that societal barriers are not hindering realization of DEIA intentions. Some of these considerations may result in common approaches in different sections of the plan, and that is acceptable, as long as the submission is not a singular approach to all sections.

DOE especially encourages applicants to form partnerships with divers and often underrepresented institutions, such as Minority Serving Institutions, labor unions, community colleges that otherwise meet the eligibility requirements.

Underrepresented institutions that meet the eligibility requirements are encouraged to lead these partnerships as the prime applicant. The DEIA section of the Plan could include engagement with underrepresented institutions to broaden the participation of disadvantaged communities and/or with local stakeholders, such as residents and businesses, entities that carry out workforce development programs, labor unions, local government, and community-based organizations that represent, support, or work with disadvantaged communities. Applicants should ensure there is transparency, accountability, and follow-through when engaging with community members and stakeholders.

Specific examples include:

- Building collaborations and partnerships with researchers and staff at Minority Serving Institutions
- Addressing barriers identified in climate surveys to remove inequities
- Providing anti-basis training and education in the project design and implementation teams
- Offering training, mentorship, education, and other support to students and early/mid-career professionals from disadvantaged communities
- Providing efforts toward improving a workplace culture of inclusion

- Developing technology and technology integration innovations to meet the needs of disadvantaged communities
- Creating partnerships with local communities, especially under-resourced and disadvantaged communities
- Voluntary recognition of a union and informing employees of their rights, regardless of their classification
- Making research products and engagement materials accessible in a greater variety of formats to increase accessibility of research outputs
- Implementing training or distributing materials to reduce stigma towards individuals with disabilities
- Designing technologies that strategically fit within the existing workforce for installation and maintenance of the potential innovation

Energy Equity

The Energy Equity section should articulate how project proposals will drive equitable access to, participation in, and distribution of the benefits produced from successful technology innovations to disadvantaged communities and groups. Intentional inclusion of energy equity requires evaluating the anticipated long-term costs and benefits that will accrue to disadvantaged groups as a result of the project, and how research questions and project plans are designed for and support historically disadvantaged communities' engagement in clean energy decisions. Similar to potential cost reductions or groundbreaking research findings resulting from the research, energy equity and justice benefits may be uncertain, occur over a long period of time, and have many factors within and outside the specific proposed research influencing them.

Applicants should describe the influencing factors, and the most likely energy equity implications of the proposed research. Applicants should describe any long-term constraints the proposed technology may pose to communities' access to natural resources and Tribal Cultural resources. There may be existing equity research available to use and citation in this description or the applicant could describe milestone-based efforts toward developing that understanding through this innovation. These near and long term outcomes may include, but are not limited to: a decrease in the percent of income a household spends on energy costs (energy burden[23]); an increase in access to low-cost capital; a decrease in environmental exposure and burdens; increases in clean energy enterprise creation and contracting (e.g., women or minority-owned business enterprises); increased parity in clean energy technology access and adoption; increases in energy democracy, including community ownership; and an increase in energy resilience.

[23] Energy burden in defined as the percentage of gross household income spent on energy costs: https://www.energy.gov/eere/slsc/low-income-community-energy-solutions

Specific examples include:

- Describing how successful innovation will support economic development in diverse geographic or demographic communities
- Creating a plan to engage equity and justice stakeholders in evaluation the broader impacts of the innovation or in the development of the research methodology
- Describe how the proposed research strategy and methodology was informed by input from a wide variety of stakeholders
- Creating a literature review of the equity and justice implications of the outcomes of the specific research if the innovation is successful, or a plan with dedicated budget and expertise (staffing or subawardee) to evaluate the potential equity implications of successful innovation outcomes.

Workforce

The Workforce section of the R&D Community Benefits Plan should articulate the future workforce implications of the innovation or a milestone-driven plan for understanding those implications. This includes documenting the skills, knowledge, and abilities that would be required of workers installing, maintaining, and operating the technology that may be derivative of the applicant's research, as well as the training pathways and their accessibility for workers to acquire the necessary skills. There may be field-specific or relevant existing research that could be cited in this section. In addition, applicants could detail the process they will use to evaluate long-term impacts on jobs, including job growth or job loss, a change in job quality, disruptions to existing industry and resulting changes to relationships between employers and employees and improvements or reductions in the ability of workers to organize for collective representation, and anything else that could result in changes to regional or national labor markets.

For additional support with developing the Workforce section of the R&D Community Benefits Plan, please refer to DOE's Community Benefits Plan Frequently Asked Questions (FAQs) webpage (https://www.energy.gov/bil/community-benefits-plan-frequently-asked-questions-faqs). This new resource, though created primarily for BIL-funded demonstration and deployment projects, may be useful for R&D projects.

Applicants will find section 2 of the FAQ ("Investing in America's Workforce") particularly helpful for understanding key federal policies, terms and concepts, as well as workforce development strategies relevant to examination of the workforce implications of applicant's proposed research.

Specific examples include:

- Outlining the challenges and opportunities for commercializing the technology in the US

- Creating a literature review of the workforce implications of the outcomes of the specific research if the innovation is successful or a plan with dedicated budget and expertise (staffing or subawardee) to evaluate the potential equity implications of successful innovation outcomes
- Creating a plan and milestones for assessing how a successful innovation will have implications for job savings for loss, either at the macroeconomic level or within specific industries
- Describing how the project will support workforce training to address needs of successful innovation
- Voluntary recognition of a union and informing employees of their rights, regardless of their classification
- Creating a plan to evaluate how a successful innovation will result in potential workforce shifts between industries or geographies

Inclusion of SMART milestones

DOE requires that the applicant's R&D Community Benefits Plan include on Specific, Measurable, Achievable, Relevant, and Timely (SMART) milestone for each budget period. An exemplar SMART milestone clearly answers the following questions:

- What needs to be accomplished?
- What measures and deliverables will be used to track progress toward accomplishment?
- What evidence suggests that the accomplishment is achievable?
- Why choose this milestone?
- When will the milestone be reached?

Appendix M – R&D Community Benefits Plan Template

Community Benefits Plan Template for Research and Development Applications

Applicant should insert here:
FOA Number and FOA Title
Organization Name
Project Title

Instructions for Use of this Template:

The purpose of this document is to summarize the specific objectives the Applicant is committing to in its Community Benefits Plan (CBP).

Important information about using this template:

- **The instructional textboxes within each section can be removed when submitting the application.**

- **All information included in this CBP must be consistent with other parts of the application.** The CBP should accurately define the work that is planned and the progress that will be expected throughout the project to be achieved.

- **Wherever possible, the objectives laid out in the CBP should be in quantifiable terms with SMART milestones**: **S**pecific, **M**easurable, **A**chievable, **R**elevant, and **T**imely – and include timelines. The Community Benefits Plan may include multiple milestones but should have at least one SMART milestone per budget period as well as one SMART end of project goal.

- The information provided in the summary table in the final section should be consistent with the commitments made throughout the CBP Template and broader Application.

- By submitting this form, Applicant acknowledges and agrees that the information provided may be distributed or made publicly available, without any restrictions or obligations to maintain confidentiality, as required by applicable laws, rules and regulations. If Applicant wishes to protect proprietary or trade secret information submitted with this CBP Template, every line and paragraph containing such information must be clearly marked as "CONFIDENTIAL" and designated with double brackets or highlighting to indicate the confidential information.

A. General Project Information

Instructions: This section asks for the applicant to provide general information on the CBP and how it integrates with the project, including critical information on the construction component, if any, and the locations and communities affected. Applicant should also provide a description of the project personnel overseeing the community benefits plan, their qualifications, and time allocated for the activities proposed.

1. High-level description of the CBP and project

Please provide description here.

Instructions for Sections B through E:

Sections B through E below should summarize the specific objectives the applicant is committing to, broken into specific commitments and tasks.

Wherever possible and relevant, each commitment or task should be stated in quantifiable or measurable terms and SMART (**S**pecific, **M**easurable, **A**chievable, **R**elevant, and **T**imely) milestones with timelines should be identified. The CBP may include multiple milestones but should have at least one SMART milestone per budget period as well as one SMART end of project goal.

If awarded, the progress towards meeting the objectives and milestones set forth in the CBPs will be included as part of the Go/No-go evaluation.

B. Community and Labor Engagement [Section omitted for R&D Template]

C. Investing in Job Quality and Workforce Continuity [Investing in America's Workforce]

Instructions: The Workforce section of the R&D Community Benefits Plan should articulate the future workforce implications of the innovation or a milestone-driven plan for understanding those implications. This includes documenting the skills, knowledge, and abilities that would be required of workers installing, maintaining, and operating the technology that may be derivative of the applicant's research, as well as the training pathways and its accessibility for workers to acquire the necessary skills.
There may be field-specific or relevant existing research that could be cited in this section. In addition, applicants could detail the process they will use to evaluate long-term impacts on jobs, including job growth or job loss, a change in job quality, disruptions to existing industry and resulting changes to relationships between employers and employees, improvements or reductions in the ability of workers to organize for collective representation, and anything else that could result in changes to regional or national labor markets.
The applicant should add or delete commitments to reflect their specific plan.

Job Quality and Workforce Continuity

For large R&D Projects that include demonstration activity, please describe the Applicant's plan to ensure that jobs created by this project are good quality and will attract and retain a skilled workforce, including the following commitments to wages and benefits, education and training investments, and worker involvement in health and safety:

[Examples]

[Commitments C1-2 omitted for R&D Template]

Commitment C3a.1: Applicant will provide above-average wages and benefits, benchmarked to occupation and industry reported by BLS:

- The minimum starting wage for production workers is $_____ per hour compared to the [75th or 90th] percentile of $____per hour for the [_____] industry.
- The minimum value of the following benefits offered to hourly workers is
    - Health insurance: $_____ per ___
    - Retirement contributions: $_____ per ___
    - PTO: ____hours per _____
    - Paid sick or family leave: _____ days per _____
    - Childcare or other caregiving financial assistance: $_____per worker or provision of on/near-site care
    - Transportation assistance: $ _____per worker_
    - Education/tuition reimbursement or financial contribution: $_____
    - Other: $_____per worker___

Commitment C3a.2: Applicant will provide workforce education and training through:

- Establishment of Labor-Management Training Partnership(s)[24]
- [Insert number of hours per worker] hours of paid on-the-job training
- Sponsoring registered apprenticeships: [insert goal number of apprentices]
- Covering costs and paid time for professional development and continuing education: [Enter certifications]
- Other:

Commitment C3a.3: Applicant will ensure workers are engaged in the design and implementation of workplace safety and health plans. Specifics include:

- [insert number of hourly workers] that will participate in health and safety committee and whether committee members will be paid for their time participating.
- Indicate which of the following, if any, the training provided will include:
    - worksite safety analysis
    - hazard prevention and control
    - safety and health training
    - anti-harassment and by-stander intervention training
    - Other: [Describe]
- Indicate the frequency of these health and safety committee planning meetings will be held.
- Indicate plans for how these safety and health plans will be considered by the company's management (e.g., when they will be reviewed and by when a decision to incorporate the recommendations will be made).

Commitment C3b: [Omitted; if project includes construction activity D&D template should be used]

C4. Documenting Knowledge, Skills, and Abilities.
Outline the Applicant's plan for documenting the knowledge, skills, and abilities of workers required for widespread deployment of the technology, under full commercialization scenario.

[Examples]

Commitment C4.1: Outlining the challenges and opportunities for commercializing the technology in the United States. [insert description here]

Commitment C4.2: Creating a literature review of the workforce implications of the outcomes of the specific research if the innovation is successful, or a plan with dedicated budget and expertise (staffing or subawardee) to evaluate the potential equity implications of successful innovation outcomes. [insert description here]

[24] For more information on labor-management partnership, see this resource.

Commitment C4.3: Creating a plan and milestones for assessing how a successful innovation will have implications for job savings or loss, either at the macroeconomic level or within specific industries. [insert description here]
Commitment C4.4: Describing how the project will support workforce training to address needs for successful innovation (see below for more examples).

Commitment C4.5: Creating a plan to evaluate how a successful innovation will result in potential workforce shifts between industries or geographies. [insert description here]

Commitment C4.6: Other commitments or pledges. [insert description here]

D. Diversity, Equity, Inclusion, and Accessibility

Instructions: The goal of the R&D Community Benefits Plan is to allow the application to illustrate engagement in critical thought about implications of how the proposed work will benefit the American people and lead to broadly shared prosperity, including for workers and disadvantaged communities. This section should summarize the applicant's plan to incorporate diversity, equity, inclusion, and accessibility (DEIA) objectives into the project.
Successful plans will not only describe how the project team seeks to increase DEIA but also will describe the overall approaches to retention, engagement, professional development, and career advancement. Specifically, they will demonstrate clear approaches to ensure all team members' strengths are meaningfully leveraged, and all members are provided opportunities and paths for career development, especially including paths for interns and trainees to secure permanent positions.
The applicant should add or delete commitments to reflect their specific plan. A non-exhaustive list of possible commitments is provided below.

For funded projects, funding recipients will be required to report on partnerships described.

Commitment D1. The applicant commits to partnering with Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, and Veteran Owned Businesses for contractor support needs.

Please describe your approach to partnering with Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses and Veteran Owned Businesses.

Commitment D1.1: [Name of partnership]
Summary of scope of work: [insert here]

Contract amount: $_____
Overall value of partnership: $_____

Commitment D2. Applicant commits to implementing a plan to reduce barriers and improve access to jobs for local and underrepresented workers, including DAC residents, those with disabilities, returning citizens, opportunity youth, and veterans.

[Examples]

Commitment D2.1: Applicant will partner with quality pre-apprenticeship or apprenticeship readiness programs[25] to foster improved access for underrepresented workers to career-track training and employment.

Please indicate how, if applicable, partnering programs specifically work to improve access for under-represented workers.

Name and description of readiness program(s): [insert here]

Commitment D2.2: Applicant will partner with training and placement programs [other than pre-apprenticeship programs] for underrepresented workers.

Name of training and placement programs: [insert here]

- Establishing and executing an inclusive recruitment strategy (e.g., a strategy to support broad recruitment for the apprenticeship programs, outreach to community-based organizations that work with prospective workers/apprentices): [Describe]

Commitment D2.3: Applicant will provide ($_____) in supports/subsidies for workers to access affordable, reliable and high-quality childcare, or other types of care.

Description of services: [insert here]

Commitment D2.4: Applicant will provide flexible work schedules.

Description of flexible work schedule program: [insert here]

[Commitments D2.5-D2.8 are not applicable to R&D projects and have been removed.]

Commitment D2.9: Applicant is offering training, mentorship, education, and other support to students and early/mid-career professionals from DAC.

[25] Explore Pre-Apprenticeship | Apprenticeship.gov
https://www.apprenticeship.gov/employers/explore-pre-apprenticeship

Commitment D2.10: Applicant is developing technology and technology integration innovations to meet the needs of DACs.

Commitment D2.11: Applicant is creating partnerships with local communities, especially under-resourced and DACs. [insert description here]

Commitment D2.12: Voluntary recognition of a union and informing employees of their rights, regardless of their classification. [insert description here]

Commitment D2.13: Applicant will make research products and engagement materials accessible in a greater variety of formats to increase accessibility of research outputs: [insert description here]

Commitment D2.14: Applicant will implement training or distribute materials to reduce stigma towards individuals with disabilities. [insert description here]

Commitment D2.15: Applicant will design technologies that strategically fit within the existing workforce for installation and maintenance of the potential innovation. [insert description here]

E. Justice40 Initiative [Energy Equity]

Instructions: This section should articulate how project proposals will drive equitable access to, participation in, and distribution of, the benefits produced from successful technology innovations to disadvantaged communities and groups. Applicants may also describe the influencing factors and equity implications of the proposed research. Applicants should describe any long-term constraints the proposed technology may pose to communities' access to natural resources and Tribal cultural resources. There may be existing equity research available to use and cite in this description, or the applicant could describe milestone-based efforts toward developing that understanding through this innovation.
These near- and long-term outcomes may include but are not limited to: a decrease in the percent of income a household spends on energy costs (energy burden); an increase in access to low-cost capital; a decrease in environmental exposure and burdens; increases in clean energy enterprise creation and contracting (e.g., women- or minority-owned business enterprises); increased parity in clean energy technology access and adoption; increases in energy democracy, including community ownership; and an increase in energy resilience.

[Examples]

[Commitments E1-E4 are not applicable to R&D projects and have been removed.]

Commitment E5.1: Benefits of research to DACs or Communities
Benefit E5.1.1: [insert description here]

- DAC that will benefit:
- How benefit will be delivered (e.g., direct or indirect, who will deliver):
- When benefit will be delivered:
- Milestones toward benefit delivery:
- Metrics to track and report on benefits:

[Commitments E6-E10 are not applicable to R&D projects and have been removed.]

Commitment E11. Applicant commits to the following R&D related activities:

[Examples]

Commitment E11.1: Describing how a successful innovation will support economic development in diverse geographic or demographic communities. [insert description here]

Commitment E11.2: Creating a plan to engage equity and justice stakeholders in evaluating the broader impacts of the innovation or in the development of the research methodology. [insert description here]

Commitment E11.3: Describing how the proposed research strategy and methodology was informed by input from a wide variety of stakeholders. [insert description here]

Commitment E11.4: Creating a literature review of the equity and justice implications of the outcomes of the specific research if the innovation is successful, or a plan with dedicated budget and expertise (staffing or sub awardee) to evaluate the potential equity implications of successful innovation outcomes. [insert description here]

F. Summary Table: Community Benefits Objectives and Outcomes

Instructions: This section should be filled in to reflect the commitments and relevant time-based milestones covered through this document.
The applicant should add or delete rows and columns so the table summarizes commitments and timelines from sections above. Red text indicates examples and should be deleted or modified to reflect applicant's plan.
· Specific dates (only include general time frames (i.e. Demonstrate XYZ result by Month 3, not Demonstrate XYZ by June 8th, 2013).
· Subcontractors, vendors or individuals by name. The award is with the prime and, as such, the CBOO should not generally reference the subcontractors.

Category and Commitment	**Existing or Planned**	**Budget Period 1 milestone**	**Budget period 2 milestone**	**Budget period 3 milestone**	**Budget period 3 milestone**
Community and Labor Engagement [Omitted]					
Investing in Job Quality and Workforce Continuity					
Minimum starting wage for permanent hourly jobs:	$__/hr				
Pay upper quintile wages for industry and occupation	☐ Yes ☐ No				
Fringe Benefits	☐ Employer-sponsored health insurance ☐ Contributions to retirement ☐ Transportation assistance ☐ Childcare assistance				
Training	☐ Contributions to labor-management training partnership ☐ Utilization of registered apprentices for at least 15% of construction jobs ☐ Paid training				

	☐ Tuition support or reimbursement				
Other Community and Labor Engagement R&D					
Diversity, Equity, Inclusion, and Accessibility	☐ Local and/or targeted recruitment efforts ☐ MWBE contracting ☐ Partner with quality pre-apprenticeship or apprenticeship readiness program[26]	*Partnerships with community-based organizations and ed/training providers for workforce needs planned.*			
Other DEIA					
Justice40 Initiative [Energy Equity]					
Identifies benefits/impacts to disadvantaged communities	☐ Yes (if yes, please list communities here) ☐ No				
Reduction in energy costs	☐ Yes ☐ No				
A decrease in environmental exposure and burdens	☐ Yes ☐ No				
An increase in access to low-cost capital	☐ Yes ☐ No				
An increase in quality job creation, the clean energy job pipeline, and job training for individuals	☐ Yes ☐ No				
Increases in clean energy enterprise creation and contracting (e.g., minority-owned or diverse business enterprises)	☐ Yes ☐ No				

[26] Explore Pre-Apprenticeship | Apprenticeship.gov
https://www.apprenticeship.gov/employers/explore-pre-apprenticeship

Increases in energy democracy, including community ownership of project assets	☐ Yes ☐ No				
Increased parity in clean energy technology access and adoption	☐ Yes ☐ No				
An increase in energy resilience	☐ Yes ☐ No				
Other Justice40					

Appendix N - Technology Gap Analysis

A Technology Gap Analysis is required as part of the final deliverables for awarded projects. An analysis of the current state of development of all the major/critical process components in the proposed process must be completed during project execution. The purpose of this effort is to provide the realistic view of all the research needs required to fully develop the technology to commercialization. The results of this analysis should indicate which components or systems should be the focus of future R&D efforts.

The Technology Gap Analysis should be coordinated and consistent with the process evaluated in the initial technical and economic feasibility study. Required elements for the Technology Gap Analysis include:

1. Brief review of the process under investigation. This should include the overall configuration of the process and a summary of the potential advantages of the process in terms of the Performance, Cost, Emissions, Market, and Safety Metrics.

2. A summary of the current level of research on key components or smaller-scale integrated systems. For each of the key process components, report the current Technology Readiness Level along with information and testing required for process scale-up and commercialization.

3. Summary table of the R&D gaps identified in #2 that should be the focus of future R&D efforts and those that are being investigated through other R&D programs. A summary description of the other R&D programs and how they are attempting to close the associated gaps should be included.

4. For commercially-available equipment, the potential vendors should be identified. A description of how the equipment offered by the vendor fits the requirements of the process should also be included.

Appendix O (a) – Basis for Techno-Economic Analysis for AOI-1F

The Techno-Economic Analysis (TEA) required as part of the final deliverables shall follow the analysis procedures documented in NETL's "*Quality Guidelines for Energy System Studies: Performing a Techno-Economic Analysis for Power Generation Plants*"[27] and "*Quality Guidelines for Energy System Studies: Performing a TEA for Carbon Conversion Technologies*"[28] to the greatest extent possible. For cases involving atmospheric reactive carbon capture, leveraging the NETL Solvent and Sorbent DAC case study reports[29,30] for guidance is recommended. Adjustments to the guidelines can be made due to the nature of the individual component technologies being assessed, and all deviations/assumptions should be specifically detailed.

Technologies that include power and heat production integrated with reactive carbon capture system should include it in their TEA according to the guidelines. It is highly recommended that the TEA present both the gross CO_2 captured for the system configuration presented (relevant to equipment sizing), as well as the net CO_2 removed when accounting for other on-site emission point sources within the total plant boundary (informative for system efficiency relating to CO_2 captured).

To properly assess the carbon conversion aspect of the reactive capture process, additional considerations must be made. To ensure that project results can be compared across different technology pathways and product markets, a transparent and consistent method for the relevant technical and economic evaluations is critical. The document, "*Quality Guidelines for Energy System Studies: Performing a TEA for Carbon Conversion Technologies*" seeks to satisfy this need. The assumptions and calculations outlined provide a common basis to facilitate comparison between conversion technology and end-use product selection. The guidelines presented are not intended as a complete assessment for a specific approach, or for a process applied to a specific location or plant, which would require far greater detail and site-specific information; these guidelines are intended to provide overarching guidance and remove uncertainty in the assessments to provide a transparent, reproducible, and comparable outcome. Deviations from the guidelines presented here, or situations not covered by these guidelines, must be explicitly stated by the TEA developer.

As specifically outlined in the documents, required elements of a complete TEA include:

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[27] Quality Guidelines for Energy System Studies: Performing a Techno-Economic Analysis for Power Generation Plants, National Energy Technology Laboratory, DOE/NETL-2015/1726, July 2015, https://netl.doe.gov/energy- analysis/details?id=711

[28] Quality Guidelines for Energy System Studies: Performing a Techno-Economic Analysis for Carbon Conversion Technologies, National Energy Technology Laboratory, DOE/NETL-2023/3870, June 2023, https://doi.org/10.2172/2203217

[29] Valentine, Jessica; Zoelle, Alexander; Homsy, Sally; Mantripragada, Hari; Kilstofte, Aaron; Sturdivan, Mike; Steutermann, Mark; Fout, Timothy (2022). Direct Air Capture Case Studies: Solvent System. United States. https://netl.doe.gov/energy-analysis/details?id=36385f18

[30] Valentine, Jessica; Zoelle, Alexander; Homsy, Sally; Mantripragada, Hari; Woods, Mark; Roy, Naksha; Kilstofte, Aaron; Sturdivan, Mike; Steutermann, Mark; Fout, Timothy (2022). Direct Air Capture Case Studies: Sorbent System. United States. https://netl.doe.gov/energy-analysis/details?id=d5860604

- General block flow diagram identifying all major process equipment for the entire process including any CO_2 source gas pretreatment steps, the reactive capture technology, product post-treatment, and balance of plant equipment (e.g., steam generation) and accompanying stream tables.
- Material and energy balances around the complete process, including electric power requirements, heating and/or cooling requirements, etc.
- System performance summary.
- Complete stream tables showing operating pressures, temperatures, compositions, and enthalpies for all streams entering or leaving major process equipment.
- Economic analysis including capital cost estimation and operation and maintenance costs.
    - Include list of equipment used to develop capital cost estimate including:
        - Key parameters and their value for equipment costing (e.g. height, diameter, heat duty, delta temperature, power consumption, etc.)
        - Individual component cost (e.g. contactors, pretreatment system, steam generation system, etc.)
- Final summary report.

For reference, the Quality Guidelines documents include additional pertinent information including, but not limited to:

- Description of common missteps and omissions
- Guidance on system boundaries
- Example performance summary and cost tables

The reported costs should be in line with the methodology reported in the Quality Guidelines.

Sensitivity analysis identifying critical overall system processes, associated operating parameters, and their impact on overall system performance (such as carbon conversion rates, capacity, carbon balance and energy use efficiencies) and economics should be performed. The analysis shall be conducted to be representative of a commercial embodiment with performance assumptions informed by performance data generated during the enacted project.

From a performance perspective, in addition to the process values required in the Specific State Point Data Table (Appendix S), the total amount of CO_2 converted per unit product and time shall be reported. From an economic perspective cost of carbon neutral product and cost of net CO_2 captured shall be reported at a minimum. Additionally, it is recommended that the attached template is completed and submitted with the TEA report. The values in this table should agree with the values throughout the report. Additional relevant entries, not included in this table, should be added.

The TEA results MUST be integrated with the life cycle analysis to indicate the ability of the process to create carbon neutral product.

The base case should be scaled for a net capture rate of 100,000 tonnes CO_2/ year. A sensitivity should be performed to account for economies of scale. The sensitivity range should include (1) the 45Q minimum of 1,000 tonnes/year for DAC technologies or 12,000 tonnes/year for capture from industrial sources, and (2) recommended scale for the specific technology.

Involvement of a variety of stakeholders is seen as an important facet to developing an effective carbon neutral technology. It is considered critical that a qualified organization with professional experience in performing this type of work conduct the TEA. *This activity shall not be viewed as a training exercise for inexperienced personnel.*

Parameter	Units	Value
Design Basis and Performance		
CO_2 Source Conditions	°F	
	psia	
	ppmv CO_2	
	mol% H_2O	
	mol% N_2	
	mol% O_2	
	Other notable constituents/ pollutants	
Auxiliary Load of Reactive Capture System	MW	
Auxiliary Load of Balance of Plant Equipment	MW	
Electrical Auxiliary Boiler Load (if applicable)	MW	
Heat Requirement (if applicable)	MW	
Heat Source	--	
Capacity Factor (CF) of Energy Source	%	
Utilization Factor (UF) of System	%	
Air Inlet to Process	lb/h	
CO_2 Capture Efficiency	%	
Gross CO_2 Capture Capacity (CF & UF = 100%)	tonnes/yr	
Net CO_2 Capture Capacity (CF & UF = 100%)	tonnes/yr	
Product Stream	lb/h	
	% product	
	Impurities	
	°F	
	psia	
Pressure Drop of CO_2 Source Across the Reactive Capture Unit	psi	
Water Consumption	lb/h	
Initial Reactant/Sorbent/Catalyst Fill	tonne	
Make-up Rate	tonne/y	
Cycle Description and Time (if any)		
Costs		
Dollar Basis	Year	
Capital Cost Accuracy	+/– %	
Process and Project Contingencies	%	
Reactive Capture System Total Plant Cost	$	
BOP Total Plant Cost	$	

Parameter	Units	Value
Initial Reactant/Sorbent/Catalyst Fill		
Initial Cost	$	
Replacement Cost	$/yr	
Unit Cost	$/tonne	
	$/tonne	
Reactant/Sorbent/Catalyst Waste Disposal	$/yr	
Natural Gas (if applicable)	$/MMBtu	
	$/yr	
Electricity	$/MWh	
	$/yr	
Other Consumables/Waste Disposal	$/yr	
Fixed O&M	$/yr	
Product cost	$/unit	
Cost of net CO_2 Captured	$/tonne	

Appendix O (b) – Basis for Techno-Economic Analysis for AOI-3F and AOI-3G

The Techno-Economic Analysis (TEA) required shall follow the analysis procedures documented in NETL's "*Quality Guidelines for Energy System Studies: Performing a Techno-Economic Analysis for Power Generation Plants*"[50] to the greatest extent possible.

Adjustments to the guidelines can be made under **AOI-3G** (industrial capture) due to the nature of the industrial facility and capture technology being modeled. Industrial facilities that include power and heat production integrated with the industrial facility should include it in their TEA according to the guidelines. The TEA shall provide the cost of the proposed capture technology to achieve at least 95% carbon capture efficiency. It is highly recommended that the TEA present both the gross CO_2 removed from flue gas for the system configuration presented (relevant to equipment sizing), as well as the net CO_2 removed when accounting for other on-site emission point sources within the total plant boundary (informative for system efficiency relating to CO_2 captured). Applicants should include a general process flow diagram identifying all major process equipment for the plant including CO_2 capture and compression systems, separation vessels, heat exchangers, pumps, compressors, etc. This analysis should include the evaluation of the proposed capture technology under a typical/actual NGPP duty cycle to determine how start-ups, shutdowns and partial load operations effect the overall performance of the system with special attention to the overall annual capture rate.

As specifically outlined in the document, required elements of a complete TEA (both **AOIs**) include:

- Material and energy balances around the complete power plant and around all major pieces of equipment there in, including all heating and cooling duties, and electric power requirements
  - For Industrial Capture – include material and energy balances around the complete capture system along with relevant integrations into the Industrial Facility.
- General block flow diagram identifying all major process equipment with complete stream tables showing operating pressures, temperatures, compositions, and enthalpies for all streams entering or leaving major process equipment
- Economic analysis that follows the NETL "*Quality Guidelines for Energy System Studies: Cost Estimation Methodology for NETL Assessments of Power Plant Performance.*"[51] The code of accounts for the capital cost estimate will follow those used in the Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity", aka the Bituminous Baseline Study (BBS). Operating and maintenance cost will be itemized and also follow the format used in the BBS.
  - Estimates for equipment and consumables unique to the process being developed. If possible, capital cost estimates for unique equipment will be made based on similar equipment that may exist for other type processes. If equipment analogs do not exist for unique equipment the developer must do a bottoms-up estimate.
- Final Summary report

For your reference, the Quality Guidelines document includes additional pertinent information including, but not limited to:

- Description of common missteps and omissions
- Guidance on system boundaries
- Example performance summary and cost tables

Involvement of a variety of stakeholders is seen as an important facet to developing an effective carbon capture technology. It is considered critical that a qualified organization with professional experience in performing this type of work conduct the TEA. *This activity shall not be viewed as a training exercise for inexperienced personnel.*

Assumptions and methodology to be used for the study are discussed below.

System Boundaries (as/if applicable to the technology proposed):

1. Delivered coal or natural gas entering the power plant, through high-pressure, high-purity CO2 stream crossing the plant boundary. For Industrial Capture, electricity source (either grid with price matching sources listed) or system designed and accounted for within the system boundaries (i.e., natural gas combined cycle with carbon capture)
2. Combustion air or intake air to air separation unit
3. Ambient air conditions
4. Flue gas to stack
5. Net electricity conditioned and sent to electric grid
6. Raw make-up water
7. Waste streams generated by the plant, including the CO_2 capture system, shall be adequately treated on-site prior to disposal either by landfill or other commercial disposal options.

Process Design Assumptions (as/if applicable to the technology proposed):

The TEA study should include at a minimum the following:

1. Site Characteristics and Ambient Conditions for each location
2. Cryogenic Air Separation Unit Design (if incorporated)
3. Boiler or Gasifier Design (if incorporated)
4. Steam or Gas Turbine Cycle Conditions (if incorporated)
5. Energy storage Unit design (if incorporated)
6. Environmental Controls and Performance
7. Balance of Plant
8. Economic Assumptions and Methodology
9. Reporting Requirements (including significant process figures, stream and performance tables, equipment lists, and cost accounts)

Design Basis for CO_2 Capture and Compression:

CO_2 Removal	**95%**

CO_2 Purity	**Satisfy 'Conceptual Design Limits' for Enhanced Oil Recovery as listed in Exhibit 2-1 of the NETL "*Quality Guidelines for Energy System Studies: CO_2 Impurity Design Parameters.*"**
CO_2 Delivery Pressure	**2,215 psia**
CO_2 Transport & Storage Cost	**$10/tonne CO_2**
Steam Extraction Location, if used	**Give location from steam source design**

Process Flow Diagram & Material Energy Balances:
To adequately provide reviewers a clear understanding of the proposed process and project, all applications (both **AOI-3F** and **AOI-3G**) must include a block flow diagram (.pdf file legible at 8.5 inches by 11 inches) and a corresponding process description. Any required integrations into power or balance of plant for the proposed CO_2 capture process so that it can be cost-effectively developed shall also be discussed. If alternative CO_2 utilization pathways are considered, all associated process steps should be included in the design.

There are no specific software requirements for developing the material and energy balances or costing the capture process. However, all material and energy balance calculations must be accurate, and equilibria, physical and thermodynamic properties must be calculated using rigorous models. Similarly, mass and heat transfer models employed must be based upon a rigorous mathematical description of transport phenomena. Methods and models used must be documented in the final report for the project.

Calculated Output from Analysis:

1. Block flow diagram and accompanying stream tables similar to Exhibits 4-32 and 4-33 of the BBS.

2. Performance Summary similar to Exhibit 4-34 and 4-35 of the BBS.

3. Air Emissions tables similar to Exhibits 4-36 of the BBS. At a minimum, the table should illustrate the CO_2 reduction in tonnes/year and ppm from NGPP or industrial facility and any other emissions that would be generated by the NGPP or industrial facility or balance of plant systems. Values for CO_2 removal should be presented in gross and net terms.

4. Carbon, sulfur, and water balances similar to Exhibits 4-37, 4-38, and 4-39 of the BBS, if applicable. Carbon and water balances are likely to be needed for all processes.

5. Itemized equipment list for equipment unique to the capture and compression systems and other equipment required for the integration of the capture and compressions systems with the plant.

6. Itemized capital cost estimate of the plant with capture and compression system similar to Exhibit 4-43 and 4-44 of the BBS. The economic analysis will be performed nominal/present day cost basis. Account 5 should account for capture system on any fossil-based power on plant site while account 15 should be added for all components of the capture system. Costs should be broken down by carbon capture system component and not just as one lump sum.

7. Itemized operating and maintenance cost estimate similar to Exhibit 4-45 of the BBS. Cost of Capture and Cost of CO_2 Avoided should be calculated for gross CO_2 captured for the total plant, the gross CO_2 captured by the capture system and net CO_2 captured and removed from the flue gas.

8. Sensitivity analysis identifying critical CO_2 capture technology and operating parameters and their impact on overall plant performance and economics. This analysis shall include the sensitivity of cost of the product and breakeven CO_2 sales price to the capital cost of the capture and compression system, as well as carbon capture cost as a function of carbon capture efficiency, for every percent efficiency point from 90% to 99%. Carbon capture efficiencies in excess of the design basis can be achieved either by the proposed carbon capture system or in combination with negative emissions technologies (NETs) including, but not limited to, direct air capture (DAC), bioenergy with carbon capture and storage (BECCS), and enhanced weathering.

9. Maximum carbon capture efficiency achievable with the proposed carbon capture technology and the technology pathways to achieve higher capture efficiencies and zero net carbon emissions. In addition, a cost curve starting from the optimal carbon capture rate relative to cost ($/tonne of CO_2 captured) for the proposed technology up to the maximum capture rate that is at least 95% will be provided.

Appendix P (a) – Life Cycle Analysis Requirements for AOI-1F Reactive Carbon Capture (RCC)

Life Cycle Analysis/Assessment (LCA) is an existing framework that is well suited to evaluate CDR and industrial capture. By design, LCA provides a holistic perspective of the potential environmental impacts of a product or process throughout the entire lifetime. This includes the extraction of raw materials through the end-of- life. Emissions to the environment (air, water, and land) are translated to a variety of potential impacts ranging from climate change to human health. Two International Organization for Standardization (ISO) standards provide the principles and framework (14040) and requirements and guidelines (14044) for conducting LCA.

Initial LCA:

This effort should result in an LCA that is in conformance with the ISO 14040/14044 standards. Given the stage of the project, it is expected that there will be significant uncertainty in some portions of the LCA. These should be addressed through the evaluation of multiple scenarios and sensitivity analyses as provided in the technology-specific guidance below.

Final LCA:

The Refined LCA is intended to be a revision of the Full LCA to reflect any changes as the project design progresses towards completion. At this stage, the Recipient should be prepared to assess specific regionalized inputs and scale-up considerations.

Specific LCA requirements are provided in the following section.

Life Cycle Analysis – Atmospheric Reactive Carbon Capture

Screening LCA (for application)

The screening life cycle analysis should be greenhouse gases only and at a minimum account for main energy inputs for the combined direct air capture and reactive carbon capture processes. The goal of the LCA is to demonstrate that the proposed atmospheric RCC project can achieve a net carbon intensity of zero or less kg CO_2e/unit of RCC product. NETL data for energy inputs should be used when available and are discussed in the sections below.

Initial LCA

The majority of the necessary inputs for the LCA should be leveraged from the Techno-Economic Analysis (TEA) (e.g., materials and energy balances, block flow diagrams, etc.). The LCA shall be conducted in accordance with the "FECM Best Practices for LCA of Direct Air Capture with Storage (DACS)."[31] Table 5 of the Best Practices document summarizes the requirements, as modified by the additional guidance provided below and by treating the reactive capture as an alternative to CO_2 transport and subsurface storage. While there is currently no guidance documents surrounding other forms of carbon dioxide removal, such as enhanced rock weathering and marine CDR), the principles of the document still largely apply; however, the project will need to assess how the atmospheric CO_2 removal of their project is in addition to that which would naturally occur. The life cycle requirements for operating the reactive capture portion of the plant shall be fully considered.

The following provides additional clarity and specificity for some items in the Best Practices.

- Required data:
    i. Separately report and account for any captured fossil CO_2 (e.g., from on-site fossil fuel combustion) from the captured atmospheric CO_2 for consistency with the functional unit
    ii. Include technical/physical flow amounts (e.g., kWh of electricity, MJ of heat) as key outputs in addition to the LCA impacts
    iii. Energy inputs to the facility including fuels and electricity
        1. For electricity inputs, a minimum of six scenarios should be modeled corresponding to different grid mix carbon intensities, available in the NETL CO2U openLCA LCI Database and the NETL CO2U LCA Documentation Spreadsheet as:
            a. Regional grid consumption mix (modeled as the Balancing Authority) based on proposed location of the project
            b. Current U.S. grid mix

[31] "FECM Best Practices for LCA of Direct Air Capture with Storage (DACS)," Office of Fossil Energy and Carbon Management, 2024, https://www.energy.gov/fecm/best-practices-life-cycle-assessment-direct-air-capture-storage-dacs.

c. 100% renewables

d. 100% grid average coal

e. 100% NGCC with CCS

f. 2050 U.S. grid mix

2. For heat inputs, the following scenarios shall be assessed using the data provided by NETL:

    a. Regional source of natural gas

    b. National average natural gas

    c. If external low-grade/waste heat is utilized for the CDR process, describe the source and availability

- LCA results:

    i. Shall be normalized to 1 kg (or other suitable unit) of reactive carbon capture product. Carbon removed from the atmosphere will be accounted for as a negative amount of CO_2. Any re-release of that CO_2 from the RCC process, or otherwise will be a positive CO_2 emission.

    ii. A contribution analysis shall be provided so that impacts can be differentiated by major operation/input

- Emissions scope:

    i. The scope of environmental impacts shall include all the impact categories listed in Section 4 of the Best Practices for LCA of DACS. To accomplish this the environmental inventory will need to include data beyond greenhouse gas emissions.

    ii. For GHG emissions, the global warming potential shall be reported using the 100-year global warming potential (GWP) characterization factors as the default values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) and the Sixth Assessment Report (AR6), sensitivity cases using the 20-year GWP values is required:

GHG	AR5 (IPCC 2013) [32]		AR6 (IPCC 2021) [33]	
	100-year (Default)	20-year	100-year (Default)	20-year
CO_2	1	1	1	1
CH_4	36	85	29.8	82.5
N_2O	298	264	273	273
SF_6	23,500	17,500	25,200	18,300

Note: These GWP characterization factors may be updated by NETL to reflect the latest science.

- Additional Resources – NETL has tools that may be helpful in completing the LCA requirement. These tools are not exhaustive but can be used to provide some life cycle inventory data for some energy and material inputs. The version of tools used for the life cycle analysis should be clearly specified in the report. The following resources are recommended:
    i. Additional General LCA guidance - CO2U LCA Guidance Document[34]
    ii. NETL Life Cycle Inventory Data – NETL CO2U openLCA LCI Database
    iii. Electricity Consumption LCI Data – NETL Grid Mix Explorer[35]

- LCA Submission Requirements for LCA Deliverables for awarded projects
    i. LCA Report – see CO2U LCA Guidance Document, Chapter 6 "Completing the NETL CO2U LCA Report Template"
    ii. LCA Model with Life Cycle Inventory Data – see CO2U LCA Guidance Document, for modeling guidance (no specific LCA software type is required)
    iii. List of all licensed LCA data used within the model (DOE will confirm or obtain license to access licensed data within the LCA model)

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[32] IPCC. (2013). *Climate Change 2013 The Physical Science Basis*. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

[33] IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved May 18, 2022, from https://www.ipcc.ch/report/ar6/wg1/

[34] *CO2U LCA Guidance Document*, National Energy Technology Laboratory, 2022, https://www.netl.doe.gov/LCA/CO2U.

[35] Grid Mix Explorer Version 4.2, National Energy Technology Laboratory, 2020, https://www.netl.doe.gov/energy-analysis/details?id=f0f94954-3627-4e9b-a5c0-c29cfe419d1c.

Final LCA

The Final LCA is intended to reflect any changes in design since the Initial LCA. All the steps for modeling and reporting should be consistent with the Full LCA description above. A qualitative discussion should also be provided to describe a summary of the changes from the Full LCA. The Refined LCA should include:

- Scale-up considerations (45Q minimum of 1,000 tonnes/year for DAC technologies and 12,000 tonnes/year for industrial sources, 100,000 tonnes/year and whatever scale is recommended for the specific technology should be compared) – economies of scale impacts
- Representation of regionalized sources of energy inputs, including contractual procurements for dedicated sources (e.g., Power Purchase Agreement [PPA])

Life Cycle Analysis –Reactive Carbon Capture from Point Sources (Power and Industrial Facilities)

Screening LCA (for application)

The screening life cycle analysis should be greenhouse gases only and at a minimum account for main energy inputs for the combined industrial plant and reactive carbon capture processes. Because this is an industrial facility, there will be at least two products in the functional unit – the product(s) from the industrial source and the product from the reactive capture process. The results should be scaled such that the scale of the reactive capture product is 1 kg (or other suitable unit) and noting the amount of industrial product that will be produced to make the 1 kg of reactive capture product. The applicants are strongly encouraged to find data on the global warming potential of the products and compare the proposed RCC system to conventional production. In other words, the GWP from the combined ISRCC process, "1 kg RCC product + 0.5 kg industrial product" is compared to "1 kg RCC product conventional + 0.5 kg industrial product". This is essentially the same comparison as will be requested in the Initial and Final LCAs discussed below with fewer inventory and documentation requirements. Additionally, applicants are encouraged to assess the same combined industrial facility and RCC process but with a captured, purified stream of CO_2 from the industrial facility transported 100 miles to a separate facility with a CO_2 conversion process. The goal of the LCA is to estimate the greenhouse gas emissions for a deployed project relative to conventional production and to show the potential benefits of the integrated process over more "traditional" CO_2 capture and conversion, where these processes are sequential rather than combined. NETL data for energy inputs should be used when available and are discussed in the sections below.

Initial LCA

The majority of the necessary inputs for the LCA should be leveraged from the Techno-Economic Analysis (TEA) (e.g., materials and energy balances, block flow diagrams, etc.). The life cycle requirements for operating the reactive capture portion of the plant shall be fully considered.

Because the CO_2 captured from the modeled industrial source with reactive carbon capture (ISRCC) technology will be used to make a product, the LCA shall follow the guidelines set forth in the NETL report - "*Carbon Dioxide Utilization Life Cycle Analysis Guidance for the U.S. DOE Office of Fossil Energy*," known as the CO2U LCA Guidance Document, or simply, the guidance document. The guidance document is part of the NETL LCA CO2U Guidance Toolkit, which provides additional support for the creation of the required LCA. The guidance document outlines the analysis requirements and how to use the supporting data and tools. As outlined in the guidance document, the LCA must compare a proposed product system, the supply chain of the proposed ISRCC project, to an appropriate comparison product system. All materials, including the guidance document can be accessed at www.netl.doe.gov/LCA/CO2U. The following shall also be accounted for:

- Development of Comparison Product Systems LCAs – greenhouse gas benefits of capture and utilization technologies requires a comparison to the current commercial process for developing the same product or service as derived from the RCC product proposed in the project. Guidance

on how to develop the Comparison Product System are contained within the CO2U LCA Guidance Document. Additionally, the project will create a Comparison Product System LCA that accounts for the industrial facility being at a different location than reactive carbon capture facility, requiring the capture, purification, and transport of the CO2 to the CO2 conversion facility. Developing this comparison is to show the benefits of co-locating and integrating the RCC with the industrial facility.

The following provides additional clarity and specificity for some items in the Best Practices.

- Required data:
    i. Include technical/physical flow amounts (e.g., kWh of electricity, MJ of heat) as key outputs in addition to the LCA impacts
    ii. Energy inputs to the facility including fuels and electricity
        1. For electricity inputs, a minimum of six scenarios should be modeled corresponding to different grid mix carbon intensities, available in the NETL CO2U openLCA LCI Database and the NETL CO2U LCA Documentation Spreadsheet as:
            a. Regional grid consumption mix (modeled as the Balancing Authority) based on proposed location of the project
            b. Current U.S. grid mix
            c. 100% renewables
            d. 100% grid average coal
            e. 100% NGCC with CCS
            f. 2050 U.S. grid mix
        2. For heat inputs, the following scenarios shall be assessed using the data provided by NETL:
            a. Regional source of natural gas
            b. National average natural gas
            c. If external low-grade/waste heat is utilized for the DAC process, describe the source and availability

- LCA results:
    i. Shall be normalized to 1 kg (or other suitable unit) of reactive carbon capture product plus however much of the industrial product is produced alongside the reactive carbon capture product.
    ii. A contribution analysis shall be provided so that impacts can be differentiated by major

operation/input

- Emissions scope:

    i. The scope of environmental impacts shall include all the impact categories listed in Section 4 of the"FECM Best Practices for LCA of Direct Air Capture with Storage (DACS)." To accomplish this the environmental inventory will need to include data beyond greenhouse gas emissions.

    ii. For GHG emissions, the global warming potential shall be reported using the 100-year global warming potential (GWP) characterization factors as the default values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) and the Sixth Assessment Report (AR6), sensitivity cases using the 20-year GWP values is required:

GHG	AR5 (IPCC 2013) [36]		AR6 (IPCC 2021) [37]	
	100-year (Default)	20-year	100-year (Default)	20-year
CO_2	1	1	1	1
CH_4	36	85	29.8	82.5
N_2O	298	264	273	273
SF_6	23,500	17,500	25,200	18,300

Note: These GWP characterization factors may be updated by NETL to reflect the latest science.

- Additional Resources – NETL has tools that may be helpful in completing the LCA requirement. These tools are not exhaustive but can be used to provide some life cycle inventory data for some energy and material inputs. The version of tools used for the life cycle analysis should be clearly specified in the report. The following resources are recommended:

    i. Additional General LCA guidance - CO2U LCA Guidance Document

    ii. NETL Life Cycle Inventory Data – NETL CO2U openLCA LCI Database

    iii. Electricity Consumption LCI Data – NETL Grid Mix Explorer

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[36] IPCC. (2013). *Climate Change 2013 The Physical Science Basis*. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

[37] IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved May 18, 2022, from https://www.ipcc.ch/report/ar6/wg1/

- LCA Submission Requirements for LCA Deliverables for awarded projects

    i. LCA Report – see CO2U LCA Guidance Document, Chapter 6 "Completing the NETL CO2U LCA Report Template"

    ii. LCA Model with Life Cycle Inventory Data – see CO2U LCA Guidance Document, for modeling guidance (no specific LCA software type is required)

    iii. List of all licensed LCA data used within the model (DOE will confirm or obtain license to access licensed data within the LCA model)

Final LCA

The Final LCA is intended to reflect any changes in design since the Initial LCA. All the steps for modeling and reporting should be consistent with the Full LCA description above. A qualitative discussion should also be provided to describe a summary of the changes from the Full LCA. The Refined LCA should include:

- Scale-up considerations (45Q minimum of 1,000 tonnes/year for DAC technologies and 12,000 tonnes/year for industrial sources, 100,000 tonnes/year and whatever scale is recommended for the specific technology should be compared) – economies of scale impacts
- Representation of regionalized sources of energy inputs, including contractual procurements for dedicated sources (e.g., Power Purchase Agreement [PPA])

Appendix P (b) – Life Cycle Analysis Requirements for AOI-3 Point Source Carbon Capture (PSCC)

Life cycle analysis (LCA) provides a holistic perspective of the potential environmental impacts of a product or process throughout the entire lifetime. This includes the extraction of raw materials through the end-of-life. Emissions to the environment (air, water, land) are translated to a variety of potential impacts ranging from climate change to human health. Two International Organization for Standardization (ISO) standards provide the principles and framework (14040) and requirements and guidelines (14044) for conducting LCA.

Applicants will submit a preliminary LCA in accordance with the application requirements described in FOA section IV, Application and Submission Information. Recipients of will submit a preliminary LCA as a separate report with the application. Recipients will complete a final LCA.

LCAs are to be conducted on the same reference plant as used for the TEA analysis. The LCAs shall be conducted to demonstrate the potential environmental impacts of reducing unit-wide carbon oxides and greenhouse gas (GHG) emissions. Applicants proposing industrial capture and hydrogen production, the scope of the LCA is cradle-to-gate, where the gate is defined as the production of industrial products ready for transport from the industrial facility. Applicants proposing capture from power generation facilities, the scope of the LCA is cradle-to-delivered electricity, inclusive of transmission of the electricity to the final customer. For combined heat and power (CHP) facilities, the scope will also include the exported heat.

Pre-LCA:
The preliminary LCA is intended to define a high-level description of life cycle considerations for the project at an early stage. If quantitative data are not available, the preliminary LCA should provide a qualitative discussion and highlight any major uncertainties and missing information.

Final LCA:
The final LCA is intended to be a revision of the pre- LCA to reflect any changes as the project validation progresses towards completion. This effort should result in an LCA that is in conformance with the ISO 14040/14044 standards. Given the stage of the project, there may be significant uncertainty in some portions of the LCA. These should be addressed through the evaluation of multiple scenarios and sensitivities analyses as provided in the technology-specific guidance below.

General LCA Guidance

1. While documentation and report do not necessarily need to follow the NETL CO2U LCA Guidance Document, all sources of life cycle inventory should be clearly documented in the application.
2. Applicants must use NETL data where possible. **Any alternative sources of life cycle inventory will need to be justified**. The following is a list of NETL life cycle inventory data sources: Additional Resources – NETL has tools that may be helpful in completing the LCA

requirement. These tools are not exhaustive but can be used to provide some life cycle inventory data for some energy and material inputs. **The version of tools used for the life cycle analysis should be clearly specified in the report.** The below list of resources is recommended, and **any alternative sources of life cycle inventory will need to be justified.**

a. Upstream dashboard version 3
b. Grid Mix Explorer 4.2
c. NETL CO2U openLCA LCI Database Version 2.1 (or latest)
d. NETL CO2U Documentation Spreadsheet

Pre-LCA Guidance

The following information should be provided or discussed in a qualitative nature for the pre-LCA:

- Process
  - High-level carbon balance of the proposed approach
  - Disposition of the captured CO_2 – will it be stored underground, converted to a useful product, or utilized in a long-lasting product
  - Define any co-products that might be produced as part the system
- Energy and Material Inputs
  - Planned sources of energy (electricity and heat)
  - Ranges of energy and material requirements per kg CO_2 captured
- Impacts
  - Discuss potential co-benefits, including the reduction in criteria air pollutants (CAPs)

Final LCA Guidance

The majority of the necessary inputs for the LCA should be leveraged from the Techno-Economic Analysis (TEA) (e.g., materials and energy balances, block flow diagrams, etc.). The following provides additional clarity and specificity for some items.

1) Required data:
   a) Report and account for any captured CO_2 from on-site fossil fuel combustion for consistency with the functional unit.

   b) Include technical/physical flow amounts (e.g., kWh of electricity, MJ of heat) as key outputs in addition to the LCA impacts.

   c) Energy inputs to the facility including fuels and electricity.
      i) For electricity inputs, a minimum of six scenarios should be modeled corresponding to different grid mix carbon intensities, available in the NETL CO2U openLCA LCI Database and the NETL CO2U LCA Documentation Spreadsheet as:
         (1) Regional grid consumption mix (modeled as the Balancing Authority) based on proposed location of hub
         (2) Current U.S. grid mix
         (3) 100% renewables

(4) 100% grid average coal
(5) 100% NGCC with CCS
(6) 2050 U.S. grid mix

ii) For heat inputs, the following scenarios shall be assessed using the data provided by NETL:
(1) Regional source of natural gas,
(2) National average natural gas,
(3) If external low-grade/waste heat is utilized for the process, describe the source and availability.

2) LCA results:
a) Shall be normalized to 1 kg of CO_2 removed from the facility
b) A contribution analysis shall be provided so that impacts can be differentiated by major operation/input

3) Emissions scope:
a) The scope of environmental impacts shall include all the additional impact categories listed in section 2.1.8.2 of the NETL CO2U LCA Guidance Document. To accomplish this the environmental inventory will need to include data beyond greenhouse gas emissions, as discussed in section 2.2.2.2. of the NETL CO2U LCA Guidance Document.
b) For GHG emissions, the global warming potential shall be reported using the 100-year global warming potential (GWP) characterization factors as the default values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) and the Sixth Assessment Report (AR6), sensitivity cases using the 20-year GWP values is required:

GHG	AR5 (IPCC 2013)[21]		AR6 (IPCC 2021)[22]	
	100-year (Default)	20-year	100-year (Default)	20-year
CO_2	1	1	1	1
CH_4	36	85	29.8	82.5
N_2O	298	264	273	273
SF_6	23,500	17,500	25,200	18,300

Note: These GWP characterization factors may be updated by NETL to reflect the latest science.

4) LCA Submission Requirements for Final Deliverables
a) LCA Report – see CO2U LCA Guidance Document, Chapter 6 “Completing the NETL CO2U LCA Report Template”
b) LCA Model with Life Cycle Inventory Data – see CO2U LCA Guidance Document, for modeling guidance (no specific LCA software type is required)

c) List of all licensed LCA data used within the model (DOE will confirm or obtain license to access licensed data within the LCA model)

Appendix Q – Technology Environmental Health & Safety Analysis

An assessment of EH&S risks is required as part of the final deliverables.

The purpose of the EH&S activity is to assess the environmental friendliness and safety of any future process based on the materials and process being proposed under the subject DOE FOA. This is the major concern for solvents in use today. Exposure to nanoparticles is also coming under increasing scrutiny by the U.S. Environmental Protection Agency (EPA), National Institute for Occupational Safety and Health (NIOSH) and others. The EH&S risk assessments shall be conducted by qualified and experienced organizations and professionals (*e.g.* environmental scientists, industrial hygienists, safety engineers). *Unanticipated or uncontrolled EH&S risks will impede commercialization of CO_2 capture and conversion technologies, and the EH&S assessment is a critical element of the development project.*

Required elements for the EH&S Assessment are:

1) All potential ancillary or incidental air and water emissions, and solid wastes produced from the proposed technology shall be identified and their magnitude estimated. In addition to solvents or sorbents used, researchers shall consider possible by-products of side reactions that might also occur in the system, accumulated waste products, and the fate of contaminants from the feed gas stream. Environmental degradation products shall be addressed. Bioaccumulation, soil mobility, and degradability shall be considered. Conditions at the point of discharge shall be examined.

2) If possible, a concise but complete and comprehensible description of the various toxicological effects of the substances identified in (1) above shall be provided. A thorough literature search shall be conducted to examine potential human health effects and ecotoxicity. Where information is lacking for a particular material, it shall be compared to similar substances or classes of substances.

3) Properties related to volatility, flammability, explosivity, other chemical reactivity, and corrosivity shall also be collected from existing databases or if necessary, through direct measurement in cases where the substance is not in common use.

4) The compliance and regulatory implications of the proposed technology shall be addressed with reference to applicable U.S. EH&S laws and associated standards including the Comprehensive Environmental Response and Liability Act of 1980 (CERCLA), Toxic Substances Control Act (TSCA), Clean Water Act (CWA), Clean Air Act (CAA), Superfund Amendments and Reauthorization Act (SARA) Title III, and the Occupational Safety and Health Act (OSHA).

5) An engineering analysis shall be conducted for any potentially hazardous materials identified to look for ways their use can be eliminated or minimized. Less hazardous materials should be substituted where possible. For any new materials being proposed, synthetic options shall be examined that may lead to similar, less-hazardous compounds with the required functionality. Possible engineering controls and other mitigation strategies shall be described as appropriate.

Precautions for safe handling and conditions for safe storage shall be identified, including any incompatibilities with other materials that may be used in the process. Waste treatment and offsite disposal options shall be examined. Accidental release measures shall also be discussed.

Appendix R – Environmental Justice Questionnaire (AOI-1 only)

In accordance with Executive Order 13985 officially titled Advancing Racial Equity and Support for Underserved Communities Through the Federal Government, applicants are required to submit a preliminary summary of environmental justice considerations of the proposed technology, process, or system. The following questions should be addressed:

(1) How does the technology rely on limited resources such as biomass, freshwater, land, and/or low-carbon energy? What is the relationship between the amount of resources used versus the amount of product formed?

(2) How does the technology remediate legacy environmental impacts of the energy industry, including environmental impacts associated with the use of coal?

(3) What is the project's waste management strategy and what are the anticipated impacts of residual waste on local residents?

(4) To what extent does the technology provide ancillary environmental benefits, such as reductions in NOx and SOx emissions, particulate matter, or hazardous pollutants?

(5) If the project involves a carbon capture retrofit technology, what are the potential co-benefits of the carbon capture technology (e.g., reduction of other hazardous air pollutants or reduction of other negative environmental impacts commonly associated with existing natural gas power plants or industrial processes)?

(6) How is the project incorporating a plan to ensure community and stakeholder input and engagement from underserved communities, which include persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality?

(7) Does the location of the project allow for activities that are economically, environmentally, and socially sustainable?

(8) Does the research undertaken enhances economic growth, energy security, and environmental quality by maximizing the sustainable use of resources for affordable and sustainable product creation?

(9) Are the products produced sustainably within an appropriate regulatory framework?

(10) Does the project expand the sustainable use of the nation's abundant resources?

(11) Do the objectives of the project help accelerate and increase the production of affordable, high-quality products that are environmentally and economically sustainable?

Appendix S – State Point Data Tables for AOI-1F

***Instructions for completing data table*:** The tables that follow in this Appendix shall be populated with data provided by the Recipient. The Recipient shall complete Table 1 in addition to any other Table(s) that relate to their proposed process concept.

Key data or estimates provided in the table(s) shall be supported with short narratives in bullet form. These bullets shall describe the sources for the individual data provided. This may be measurements made directly by the Recipient and shall identify the apparatus and methodology used in the measurement(s). Other acceptable sources of data are the open literature (with citation and description), or estimated or extrapolated data (with description of method/model used for the estimate, or the procedure used for extrapolation). Arguments supported by theory/mechanisms shall be provided for projected performance for new, advanced solvent, sorbent, or membrane materials.

Table 1. State-Point Data for Overall System

	Units	Measured/ Estimated Performance	Projected Performance
Overall Process			
Scale	tonne $CO_{2(net)}$/year		
Reactive Capture System Thermal Energy Requirements	GJ/tonne $CO_{2(net)}$		
Total Thermal Energy Requirements	GJ/tonne $CO_{2(net)}$		
Required Temperature of Thermal Energy	°C		
Reactive Capture System Electricity Energy Requirements	GJ/tonne $CO_{2(net)}$		
Total Electricity Energy Requirements	GJ/tonne $CO_{2(net)}$		
Land Requirements	m^2 or acres		
Water requirements	Tonnes/yr or (gallons per minute)		
Volumetric Productivity	gmol $CO_{2(net)}$ / m^3 capture media / time		

Carbon Capture Efficiency (single pass)	%		
Overall Carbon Capture Efficiency	%		
Pressure Drop	Pa		
		Proposed/Estimated	
CO_2 Source (Atmosphere or Point Source)	-		
CO_2 Source Concentration	% mol or ppmv		
Reactive Capture Technology	-		
CO_2 Conversion Pathway	-		
CO_2 End Use	-		

Notes

$CO_{2(net)}$ – The net amount of CO_2 captured, minus CO_2 emissions generated by the process.

Total thermal and electricity energy requirements – Encompass the entire process, including pre-treatment, reactive capture process operation, reactive capture media conditioning, regeneration, drying, balance of plant systems etc.

Table 2. State-Point Data for Solvent Based Systems

	Units	Measured/ Estimated Performance	Projected Performance
Pure Solvent			
Molecular Weight	mol^{-1}		
Normal Boiling Point	°C		
Normal Freezing Point	°C		
Vapor Pressure @ 15°C	bar		
Working Solution			
Concentration	kg/kg		
Specific Gravity (15°C/15°C)	-		
Specific Heat Capacity @ STP	kJ/kg·K		
Viscosity @ STP	cP		
Surface Tension @ STP	dyn/cm		
CO_2 Mass Transfer Rate [K_L]	m/s		
CO_2 Reaction Rate	-		
Thermal Conductivity	W/(m·K)		
Absorption			
Pressure	bar		
Temperature	°C		
Equilibrium CO_2 Loading	gmol CO_2/kg		
Heat of Absorption	kJ/kg CO2		
Solution Viscosity	cP		
Desorption (if utilized)			
Pressure	bar		
Temperature	°C		
Equilibrium CO_2 Loading	gmol CO_2/kg		
Heat of Desorption	kJ/kg CO2		
Degradation	(% Capacity fade/cycle)		

Notes:

STP – Standard Temperature and Pressure (0°C, 1 atm)

Pure Solvent – Agent(s), working alone or as a component of a working solution, responsible for enhanced CO_2 absorption. For example: the amine monoethanolamine (MEA) in an aqueous solution.

Working Solution – The solute-free (*i.e.,* CO_2-free) liquid solution used as the working solvent in the absorption/desorption process. For example: the liquid mixture of MEA and water.

Absorption – The conditions of interest for absorption are those that prevail at maximum solvent loading, which typically occurs at the bottom of the absorption column. Measured data are preferable to estimated data.

Desorption – The conditions of interest for desorption are those that prevail at minimum solvent loading, which typically occurs at the bottom of the desorption column. Operating pressure and temperature for the desorber/stripper are process dependent. Measured data are preferable to estimated data.

Pressure – The pressure of CO_2 in equilibrium with the solution. If the vapor phase is pure CO_2, this is the total pressure, and if it is a mixture of gases, this is the partial pressure of CO_2.

Concentration – Mass fraction of pure solvent in working solution.

Loading – The basis for CO_2 loading is moles of pure solvent.

Mass Transfer Rate – Overall liquid phase mass transfer coefficient.

CO_2 Reaction Rate – A characterization of the CO_2 absorption trend with respect to time, as complete in the range of time as possible.

Table 3. State-Point Data for Sorbent Based Systems

	Units	Measured Performance (Powder form)	Projected or Measured Performance (structured material system)
Sorbent			
True Density @ STP	kg/m^3		
Bulk Density	kg/m^3		
Average Particle Diameter	mm		
Particle Void Fraction	m^3/m^3		
Packing Density	m^2/m^3		
Solid Heat Capacity @ STP	kJ/kg·K		
Crush Strength	kg_f		
Attrition Index	-		
Thermal Conductivity	W/(m·K)		
Adsorption			
Pressure	bar		
Temperature	°C		
Equilibrium Loading	gmol CO_2/kg		
Heat of Adsorption	kJ/gmol CO_2		
CO_2 Adsorption Kinetics	gmol/time		
Desorption (if utilized)			
Pressure	bar		
Temperature	°C		
Equilibrium Loading	gmol CO_2/kg		
Heat of Desorption	kJ/gmol CO_2		
CO_2 Desorption Kinetics	gmol/time		
Degradation	(% Capacity fade/cycle)		

Notes:

STP – Standard Temperature and Pressure (0°C, 1 atm).

Sorbent – Adsorbate-free (*i.e.,* CO_2-free) and dry material as used in adsorption/desorption cycle.

Adsorption – The conditions of interest for adsorption are those that prevail at maximum sorbent loading. Measured data are preferable to estimated data.

Desorption – The conditions of interest for desorption are those that prevail at minimum sorbent loading. Operating pressure and temperature for the desorber/stripper are process dependent. Measured data are preferable to estimated data.

Pressure – The pressure of CO_2 in equilibrium with the sorbent. If the vapor phase is pure CO_2, this is the total pressure, and if it is a mixture of gases, this is the partial pressure of CO_2.

Packing Density – Ratio of the active sorbent area to the bulk sorbent volume.

Loading – The basis for CO_2 loading is mass of dry sorbent.

Kinetics – A characterization of the CO_2 adsorption/desorption trend with respect to time, as complete in the range of time as possible.

Table 4. State-Point Data for Membrane Based Systems

	Units	Measured/ Estimated Performance	Projected Performance
Materials Properties			
Materials of Fabrication for Selective Layer			
Materials of Fabrication for Support Layer (if applicable)			
Nominal Thickness of Selective Layer (μm)			
Membrane Geometry			
Max Trans-Membrane Pressure	bar		
Hours tested without significant degradation			
Membrane Performance			
Temperature	°C		
Pressure Normalized Flux for Permeate (CO_2)	GPU or equivalent		
CO_2/H_2O Selectivity	-		
CO_2/N_2 Selectivity	-		
Type of Measurement (Ideal or mixed gas)	-		
Proposed Module Design			
Flow Arrangement	-		
Packing Density	m^2/m^3		
Shell-Side Fluid	-		

Notes:

Membrane Geometry – Flat discs or sheets, hollow fibers, tubes, etc.

Pressure Normalized Flux – For materials that display a linear dependence of flux on partial pressure differential, this is equivalent to the membrane's permeance.

GPU – Gas Permeation Unit, which is equivalent to 10^{-6} $cm^3/(cm^2 \cdot s \cdot cmHg)$ at 1 atm and 0°C. For non-linear materials, the dimensional units reported shall be based on flux measured in $cm^3/(cm^2 \cdot s)$ (at 1 atm and 0°C) with pressures measured in cm Hg. Note: 1 GPU = 3.3464×10^{-6} $kgmol/(m^2 \cdot s \cdot kPa)$ [SI units]

Type of Measurement – Either mixed or pure gas measurements; projected permeance and

selectivities shall be for mixture of gases found in de-sulfurized flue gas.

Flow Arrangement – Typical gas-separation module designs include spiral-wound sheets, hollow-fiber bundles, shell-and-tube, and plate-and-frame, which result in either co-current, counter-current, crossflow arrangements, or some complex combination of these.

Packing Density – Ratio of the active surface area of the membrane to the volume of the module.

Shell-Side Fluid – Either the permeate or retentate stream.

Table 5. State-Point Data for BiCRS Systems

	Units	Measured/ Estimated Performance	Projected Performance
Biomass Source			
Biomass Category (e.g., logging residue, whole trees, crop residues, etc.)	-		
Biomass type (e.g., forest residue, hybrid poplar, corn stover, etc.)	-		
% Carbon, Raw	% mass		
Pre-treatment method	-		
% Carbon, after pre-treatment	% mass		
BiCRS Technology			
Technology/CO_2 storage method (e.g., pyrolysis with CCS, gasification with CCS, combustion with CCS, conversion, burial, sinking, bioliquid injection)	-		
Products produced (e.g., hydrogen, grid electricity, liquid fuels, biochar, etc.)			
Prior Testing			
Location	-		
Scale	tCO2e removed/d		
Technology Readiness Level	-		
Hours of continuous operation	hrs.		
Total Energy Required	kJ/kg product		
Total Heat Energy Required	kJ/kg product		
Required Temperature of Thermal energy	°C		

Total Electricity Required	kWh/kg product		
Land Requirements	m2 or acres		
Water requirements	Tonnes/yr or (gallons per minute)		

Table 6. State Point Data for Algae-based Marine Systems

	Units	Measured/ Current Performance	Projected/ Target Performance
Algae Characteristics			
Proposed Algae Strain	-		
Algae Cultivation			
Method of Cultivation	-	(Pond, PBR or other-describe)	
Water Source			
Nutrient Source - N			
Nutrient Source - P			
Scale of prior operation – CO_2 fed	kg/h		
Tested surface area	m2		
Test depth of water	cm		
Algae Productivity			
Peak Productivity	g/m2/day		
Annual Average Productivity	g/m2/day		
Prior Testing			
Location			
Scale	tonne CO2 removed/d		
Hours of continuous operation	h		

Table 7. State-Point Data for Mineralization Based Systems

	Units	Measured Performance (Powder form)	Projected or Measured Performance (structured material system)
Reaction Thermodynamics			
Balanced Chemical Equation	mol-1		
ΔH°_{rxn} (Calculated from standard enthalpies of formation)	kJ/mol		
ΔG°_{rxn} (Calculated from standard free energies of formation)	kJ/mol		
Solid material as contacted			
True Density @ STP	kg/m3		
Bulk Density	kg/m3		
Average Particle Diameter	mm		
Particle Void Fraction	m3/m3		
Packing Density	m2/m3		
Solid Heat Capacity @ STP	kJ/kg·K		
Crush Strength	kgf		
Thermal Conductivity	W/(m·K)		
Adsorption			
Pressure	bar		
Temperature	°C		
Equilibrium Loading	gmol CO2/kg		
Heat of Adsorption	kJ/gmol CO2		
CO_2 Adsorption Kinetics	gmol/time		
Desorption (if utilized)			
Pressure	bar		
Temperature	°C		
Equilibrium Loading	gmol CO2/kg		

Heat of Desorption	kJ/gmol CO2		
CO_2 Desorption Kinetics	gmol/time		
Prior Testing			
Location			
Scale	tonne CO2/d		
CO_2 concentration in feed stream (e.g, atmosphere, flue gas, process stream)	%		
Hours of continuous operation	h		
CO_2 capture efficiency during longest test	%		
Mineral Make-up rate	%/yr		

***Notes*:**
STP – Standard Temperature and Pressure (0°C, 1 atm)
Sorbent – Adsorbate-free (*i.e.,* CO_2-free) and dry material as used in adsorption/desorption cycle.
Adsorption – The conditions of interest for adsorption are those that prevail at maximum sorbent loading. Measured data are preferable to estimated data.
Desorption – The conditions of interest for desorption are those that prevail at minimum sorbent loading. Operating pressure and temperature for the desorber/stripper are process dependent. Measured data are preferable to estimated data.
Pressure – The pressure of CO_2 in equilibrium with the sorbent. If the vapor phase is pure CO_2, this is the total pressure, and if it is a mixture of gases, this is the partial pressure of CO_2.
Packing Density – Ratio of the active sorbent area to the bulk sorbent volume.
Loading – The basis for CO_2 loading is mass of dry sorbent.
Kinetics – A characterization of the CO_2 adsorption/desorption trend with respect to time, as complete in the range of time as possible.

Table 8. State-Point Data for Electrochemical Conversion Systems

	Units	Measured/Current Performance	Projected/Target Performance
Reaction Thermodynamics			
Balanced Chemical Equation	mol^{-1}		
$\Delta H°_{rxn}$ (Calculated from standard enthalpies of formation)	kJ/mol		
$\Delta G°_{rxn}$ (Calculated from standard free energies of formation)	kJ/mol		
Cell Operating Conditions			
Nominal Cell Potential	V		
Nominal Current Density	mA/cm^2		
Nominal Power Density	mW/cm^2		
Nominal Operating Temperature	°C		
ΔT Across Cell	°C		
Operating Pressure	atm		
Cell/System Performance			
Fuel/Steam Utilization	%		
Air Utilization	%		
Degradation Rate	%/1000 h		
Electricity Production (Fuel Cell)	kW		
Product Production (Electrolysis)	kg/h		
Electrical Efficiency (Fuel Cell)	%		
Faradaic Efficiency (Electrolysis)	%		
Carbon Conversion Metrics			
CO_2 Conversion Efficiency	%		
CO_2 Conversion Intensity	%		
Required Purchase Price for CO_2	$/tonne CO2		
Cell Product Properties			
Commercial Product			
Cost of Electricity (Fuel Cell)	$/MWh		
Cost of Product (Electrolysis)	$/kg		
Market Product Properties		**Current**	
Commercial Product			
Cost of Electricity (Fuel Cell)	$/MWh		
Cost of Product (Electrolysis)	$/kg		

***Notes*:**

CO_2 Conversion Efficiency – The amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of CO_2 fed to the carbon conversion process. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 36.

CO_2 Conversion Intensity – Carbon intensity is defined as the amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of the desired product. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 37.
Required Purchase Price for CO_2 –The price at which the carbon conversion technology can afford to purchase CO_2 and remain at cost parity with the current state of the art production method. The metric is dependent on the price of the product made from CO_2, the capital charges involved with producing the product, which include return on investment for the conversion facility, the fixed operational costs, and the variable costs aside from the fluctuating cost of CO_2. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 39.

Table 9. State-Point Data for Catalytic Conversion Systems to Organic Products

	Units	Measured/Current Performance	Projected/Target Performance
Synthesis Pathway Steps			
Step 1 (balanced chemical equation based on CO2)	mol-1		
Step 2 (balanced chemical equation based on CO2)	mol-1		
Step n (balanced chemical equation based on CO2)	mol-1		
Source of external intermediate 1 (e.g., natural gas, oil, renewable energy, etc.)			
Source of external intermediate 2 (e.g., natural gas, oil, renewable energy, etc.)			
Source of external intermediate n (e.g., natural gas, oil, renewable energy, etc.)			
Reaction Thermodynamics			
Reaction			
ΔH°rxn (Calculated from standard enthalpies of formation)	kJ/mol		
ΔG°rxn (Calculated from standard free energies of formation)	kJ/mol		
Conditions		(range)	(range)
CO_2 Source			
Catalyst			
Operating Pressure	bar		
CO2 Partial Pressure	bar		
Temperature	°C		
Performance		(range)	(minimum)
Nominal Residence Time			
Selectivity to Desired Product	%		
Product Composition		(range)	(optimal)
Desired Product	mol%		
Desirable Co-Products	mol%		
“ “	mol%		
Undesired By-Products	mol%		
“ “	mol%		
Grand Total	mol%	--	100%
Carbon Conversion Metrics			
CO2 Conversion Efficiency	%		
CO2 Conversion Intensity	%		

Required Purchase Price for CO2	$/tonne CO2		

Notes:

Synthesis Pathway Steps – Balanced equations for each step in the synthesis pathway. Intermediates provided from external sources (e.g., ethane, methane, hydrogen, etc.) should be shown in **BOLD** type. Intermediates generated as part of the synthesis pathway should be in standard type.

Reaction Thermodynamics – ΔH^0_{rxn} and ΔG^0_{rxn} at 25°C, 1 atm. If Standard Enthalpies and Gibbs Free Energies of Formation cannot be found for some chemical species in the proposed chemical reaction(s), they should be estimated; however, the method used must be clearly referenced or described.

Reaction – Identify the type of reaction for example, thermochemical, electrochemical, photochemical, etc.

CO_2 Source – Identify the CO_2 source for example, coal-fired flue gas, natural gas-fired flue gas, pure CO_2, etc.

Catalyst – Identify the catalyst composition.

Nominal Residence Time – Reactor residence times are difficult to quantify, especially early in any laboratory-scale development effort. Definitions vary based on whether the reaction is being carried out in a batch or continuous reactor and whether a homogeneous, heterogeneous or no catalyst is being used. For the calculation of Nominal Residence Time, the Recipient should use the following equations:

For experimental systems involving batch reactors:

{Nominal Residence Time} = {Length of Time Reactor is Operated}

For continuous reactors operated at steady state, employing a solid catalyst:

{Nominal Residence Time} = {Mass of Catalyst in Reactor} / {Total Mass Flowrate into Reactor} For continuous reactors operated at steady state, employing a homogenous or no catalyst:

{Nominal Residence Time} = {Volume of Reactor} / {Total Volume Flowrate into Reactor}

Selectivity to Desired Product – The fraction of the carbon in the Desired Product to the total amount of available carbon reacted, expressed as mole-percent:

Selectivity to Desired Product = 100 × (moles of carbon from CO_2 in Desired Product) / (moles CO_2 reacted)

Product Composition – Recipient should define the primary product of interest. Normally, this is either the highest value or largest volume compound or material produced. Desirable co-products are any other reaction products of sufficient value that they would be profitable for the producer to recover, purify, transport and market. Whether to maximize or minimize production of these co-products is an economic decision.

Unwanted by-products are produced from undesired side reactions, which may result from system upsets or may be an unavoidable consequence of the current state of technology development.

CO_2 Conversion Efficiency – Defined as the amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of CO_2 fed to the carbon conversion process. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 36.

CO_2 Conversion Intensity – Defined as the amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of the desired product. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 37.

Required Purchase Price for CO_2 – This metric represents the price at which the carbon conversion technology can afford to purchase CO_2 and remain at cost parity with the current state of the art production method. The metric is dependent on the price of the product made from CO_2, the capital charges involved with producing the product, which include return on investment for the conversion facility, the fixed operational costs, and the variable costs aside from the fluctuating cost of CO_2. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 39.

Table 10. State-Point Data for Production of Inorganic Materials (Solid Carbon Products)

	Units	Measured/Current Performance	Projected/Target Performance
Reaction Thermodynamics			
Reaction			
Balanced Chemical Equation	mol^{-1}		
$\Delta H°_{rxn}$ (calculated from standard enthalpies of formation)	kJ/mol		
$\Delta G°_{rxn}$ (calculated from free energies of formation)	kJ/mol		
Reaction Conditions			
CO_2 Source	-		
Catalyst	-		
Pressure	bar		
CO_2 Partial Pressure	bar		
Temperature	°C		
Nominal Residence Time	sec		
Once-Through Performance			
CO_2 Conversion	%		
Selectivity to Desired Product	%		
Yield of Desired Product	%		
Product Composition			
Desired Product	-		
Main Product Impurities	-		
Purity of Finished Product	%		
Product Production	kg/h		
Co-Products	-		
Co-Product Production	kg/h		
Product Properties			
Density	kg/m^3		
Particle Size	µm		
Surface Area	m^2/g		
Carbon Conversion Metrics			
CO_2 Conversion Efficiency	%		
CO_2 Conversion Intensity	%		
Required Purchase Price for CO_2	$/tonne CO_2		
Commercial Product Properties		**Current**	

Density	kg/m^3	
Particle Size	microns	
Surface Area	m^2/g	
U.S. Market Size	tonnes/yr	
Global Market Size	tonnes/yr	
Market Price	$/kg	

Notes:

Reaction Thermodynamics – ΔH^0_{rxn} and ΔG^0_{rxn} at 25°C, 1 atm. If Standard Enthalpies and Gibbs Free Energies of Formation cannot be found for some chemical species in the proposed chemical reaction(s), they should be estimated; however, the method used must be clearly referenced or described.

Reaction – Identify the type of reaction for example, thermochemical, electrochemical, photochemical, etc.

CO_2 Source – Identify the CO_2 source for example, coal-fired flue gas, natural gas-fired flue gas, pure CO_2, etc.

Catalyst – Identify the catalyst composition.

Nominal Residence Time – For the calculation of Nominal Residence Time, the applicant should use the following equations:

For experimental systems involving batch reactors:

{Nominal Residence Time} = {Length of Time Reactor is Operated}

For continuous reactors operated at steady state, employing a solid catalyst:

{Nominal Residence Time} = {Mass of Catalyst in Reactor} / {Total Mass Flowrate into Reactor} For continuous reactors operated at steady state, employing a homogenous or no catalyst:

{Nominal Residence Time} = {Volume of Reactor} / {Total Volume Flowrate into Reactor}

Once-Through Performance – Should be reported for the reaction(s) based on moles of CO_2 in the feed.

CO_2 Conversion – The quotient of the CO_2 reacted to the initial CO_2 in the feed, expressed as mole- percent:

CO_2 Conversion = 100 × (moles CO_2 reacted) / (moles CO_2 in feed)

Selectivity to Desired Product – The quotient of the moles of carbon from CO_2 in the Desired Product to the moles of CO_2 reacted, expressed as mole-percent:

Selectivity to Desired Product = 100 × (moles of carbon from CO_2 in Desired Product) / (moles CO_2 reacted)

Yield of Desired Product – (CO_2 Conversion) × (Selectivity to Desired Product) / 100

Desired Product – Identify the desired product, for example graphene, carbon nanotubes, carbon black, etc. Finished commercial carbon products are defined by the performance specifications required for their specific uses. As used here, the term 'Desired Product'

refers to the morphology of the carbon: nanotubes, graphene or graphitic sheets or flakes, etc., and does not include impurities left in the finished product.
Main Product Impurities – Identify the main product impurities for the example byproducts contaminants, etc. that are not separated from the finished product.
Purity of Finished Product = (Mass of the desired product) / (Total mass of the finished product)
Where the 'Total mass of the product' is the mass of the desired product plus the mass of the productimpurities or contaminants.
Product Production – The mass flowrate of the desired product produced during the proposed testing.
Co-Products – List the main Co-product, if applicable.
Co-Product Production – The mass flowrate of the co-product produced during the proposed testing.
Product Properties – The properties of the desired product produced during testing.
CO_2 Conversion Efficiency – Defined as the amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of CO_2 fed to the carbon conversion process. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 36.
CO_2 Conversion Intensity – Defined as the amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of the desired product. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 37.
Required Purchase Price for CO_2 – This metric represents the price at which the carbon conversion technology can afford to purchase CO_2 and remain at cost parity with the current state of the art production method. The metric is dependent on the price of the product made from CO_2, the capital charges involved with producing the product, which include return on investment for the conversion facility, the fixed operational costs, and the variable costs aside from the fluctuating cost of CO_2. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 39.
Commercial Product Properties – The properties of the commercial product that the finished product of the proposed technology plans to produce or compete against.

Table 11. State-Point Data for Production of Inorganic Materials (Maximizing Carbon Uptake in Concrete and Cement)

	Units	Measured/Current Performance	Projected/Target Performance
Reaction Thermodynamics			
Balanced Chemical Equation	mol^{-1}		
$\Delta H°_{rxn}$ (Calculated from standard enthalpies of formation)	kJ/mol		
$\Delta G°_{rxn}$ (Calculated from standard free energies of formation)	kJ/mol		
Reaction Conditions			
CO_2 Source			
Pressure	bar		
CO_2 Partial Pressure	bar		
Temperature	°C		
Nominal Residence Time	s		
Alkaline Reactant Source			
Process Route	direct/ indirect		
Once-Through Performance			
CO_2 Conversion	%		
CO_2 Uptake Potential	g-CO_2/g material		
CO_2 Uptake Actual	g-CO_2/g material		
Product Properties			
Desired Product			
Compressive Strength	MPa		
Density	kg/m^3		
Product Production	kg/h		
Carbon Conversion Metrics			
CO_2 Conversion Efficiency	%		
CO_2 Conversion Intensity	%		
Required Purchase Price for CO_2	\$/tonne CO_2		
Commercial Product Properties		**Current**	
Commercial Product			
Compressive Strength	MPa		
Density	kg/m^3		
U.S. Market Size	tonnes/yr		

Global Market Size	tonnes/yr	
Market Price	$/kg	

Notes

Reaction Thermodynamics – ΔH^0_{rxn} and ΔG^0_{rxn} at 25°C, 1 atm. If Standard Enthalpies and Gibbs Free Energies of Formation cannot be found for some chemical species in the proposed chemical reaction(s), they should be estimated; however, the method used must be clearly referenced or described.

CO_2 Source – Identify the CO_2 source for example, coal-fired flue gas, natural gas-fired flue gas, pure CO_2, etc.

Nominal Residence Time – For the calculation of Nominal Residence Time, the applicant should use the following equations:

For experimental systems involving batch reactors:

{Nominal Residence Time} = {Length of Time Reactor is Operated}

For continuous reactors operated at steady state, employing a solid catalyst:

{Nominal Residence Time} = {Mass of Catalyst in Reactor} / {Total Mass Flowrate into Reactor} For continuous reactors operated at steady state, employing a homogenous or no catalyst:

{Nominal Residence Time} = {Volume of Reactor} / {Total Volume Flowrate into Reactor}

Once-Through Performance – Should be reported for the reaction(s) based on moles of CO_2 in the feed.

Alkaline Reactant Source – Identify the Alkaline Reactant Source for example, fly ash, slags, mine tailings, etc.

Process Route – Identify the process as direct (carbonation of the feed occurs as a single step withoutextraction or dissolution of the mineral ions) or indirect (extraction or dissolution of mineral ions fromthe feed occurs in a separate step before carbonation)

Once-Through Performance – Should be reported for the reaction(s) based on moles of CO_2 in the feed.

CO_2 Conversion – The quotient of the CO_2 reacted to the initial CO_2 in the feed, expressed as mole- percent:

CO_2 Conversion = 100 × (moles CO_2 reacted) / (moles CO_2 in feed)

CO_2 Uptake Potential – The mass of CO_2 that can theoretically be reacted per mass of the unreactedmaterial that produces the final product after carbonation

CO_2 Uptake Actual – The actual mass of CO_2 reacted per mass of the unreacted material that produces the final product after carbonation

Product Properties – The properties of the desired product produced during testing.

Compressive Strength – Following 28 days of aging

CO_2 Conversion Efficiency – Defined as the amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of CO_2 fed to the carbon conversion process. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 36.
CO_2 Conversion Intensity – Defined as the amount of CO_2 utilized (CO_2 in – CO_2 out) on a mass basis per unit amount of the desired product. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 37.
Required Purchase Price for CO_2 – This metric represents the price at which the carbon conversion technology can afford to purchase CO_2 and remain at cost parity with the current state of the art production method. The metric is dependent on the price of the product made from CO_2, the capital charges involved with producing the product, which include return on investment for the conversion facility, the fixed operational costs, and the variable costs aside from the fluctuating cost of CO_2. Source: NETL, Performing a TEA for Carbon Conversion Technologies, page 39.
Commercial Product Properties – The properties of the commercial product that the finished product of the proposed technology plans to produce or compete against.

Appendix T – State Point Data Tables for AOI 3

Instructions for completing data tables: The tables that follow in this appendix shall be populated with data provided by the Applicant and included as an attachment to the application. Applicants shall complete the appropriate Table(s) 1-3 that relate to their proposed process concept. Merit scoring of application will correspond to the completeness of the data table and supporting information.

At the time that the application is submitted, the applicant should have achieved optimal performance for the solvent, sorbent or membrane material system proposed. Applicants are required to provide the demonstrated performance data for their solvent, sorbent or membrane material.

Key data or estimates provided in the table(s) shall be supported with short narratives in bullet form within the Scientific and Technical Merit section. These bullets shall describe the sources for the individual data provided. This may be measurements made directly by the Applicant and shall identify the apparatus and methodology used in the measurement(s). Due to page limitations, citations may be utilized to describe the sources for the individual data provided by the applicant or others, or by example calculations for noncritical data. Other acceptable sources of data are the open literature (with citation and description), or estimated or extrapolated data (with description of method/model used for the estimate, or the procedure used for extrapolation). Arguments supported by theory/mechanisms shall be provided for projected performance for new, advanced solvent, sorbent or membrane materials.

Table 1. State-Point Data for Solvent Based Systems

	Units	Measured/ Estimated Performance	Projected Performance
Pure Solvent			
Molecular Weight	mol^{-1}		
Normal Boiling Point	°C		
Normal Freezing Point	°C		
Vapor Pressure @ 15°C	bar		
Working Solution			
Concentration	kg/kg		
Specific Gravity (15 °C/15 °C)	-		
Specific Heat Capacity @ STP	kJ/kg·K		
Viscosity @ STP	cP		
Surface Tension @ STP	dyn/cm		

CO_2 Mass Transfer Rate [K_L]	m/s		
CO_2 Reaction Rate	-		
Thermal Conductivity	W/(m·K)		
Absorption			
Pressure	bar		
Temperature	°C		
Equilibrium CO_2 Loading	gmol CO_2/kg		
Heat of Absorption	kJ/kg CO_2		
Solution Viscosity	cP		
Desorption			
Pressure	bar		
Temperature	°C		
Equilibrium CO_2 Loading	gmol CO_2/kg		
Heat of Desorption	kJ/kg CO_2		
Degradation	(% Capacity fade/cycle)		
Degradation Products and Concentrations (nitrosamines, aldehydes, …)	ppb		
Emissions: Criteria pollutants and capture system/media secondary emissions	ppb		
Characteristics of Previous Testing			
Location			
The following information should be provided for the longest steady-state duration test performed at bench scale or pilot scale			
Scale	tCO_2/year		
Duration of Long-Term Test (consecutive hours)	hr		
CO_2 concentration in the feed stream (e.g., flue gas, process stream)	Mol %		
Carbon Capture Efficiency	%		
Solvent Make-up rate	%/yr		
Reboiler Duty	KJ/Kg CO_2		
Details on solvent reclamation or refreshing			

CO_2 Product Purity	Mol % dry		
CO_2 Product Oxygen Concentration	Mol% (or ppm)		

***Definitions for Table 1*:**
STP – Standard Temperature and Pressure (15 °C, 1 atm)
Pure Solvent – Agent(s), working alone or as a component of a working solution, responsible for enhanced CO_2 absorption. For example: the amine monoethanolamine (MEA) in an aqueous solution.
Working Solution – The solute-free (*i.e.* CO_2-free) liquid solution used as the working solvent in the absorption/desorption process. For example: the liquid mixture of MEA and water.
Absorption – The conditions of interest for absorption are those that prevail at maximum solvent loading, which typically occurs at the bottom of the absorption column. Measured data are preferable to estimated data.
Desorption – The conditions of interest for desorption are those that prevail at minimum solvent loading, which typically occurs at the bottom of the desorption column. Operating pressure and temperature for the desorber/stripper are process dependent. Measured data are preferable to estimated data.
Pressure – The pressure of CO_2 in equilibrium with the solution. If the vapor phase is pure CO_2, this is the total pressure, and if it is a mixture of gases, this is the partial pressure of CO_2.
Concentration – Mass fraction of pure solvent in working solution.
Loading – The basis for CO_2 loading is moles of pure solvent.
Mass Transfer Rate – Overall liquid phase mass transfer coefficient.
CO_2 Reaction Rate – A characterization of the CO_2 absorption trend with respect to time, as complete in the range of time as possible.
CO_2 Product Purity – Average purity of the CO_2 product from the capture system during the long-term testing
CO_2 Product Oxygen Concentration – Oxygen content of the CO_2 produced during the long-term testing

Table 2. State-Point Data for Sorbent Based Systems

	Units	Measured/ Estimated Performance	Projected Performance
Sorbent			
True Density @ STP	kg/m^3		
Bulk Density	kg/m^3		
Average Particle Diameter	mm		
Particle Void Fraction	m^3/m^3		
Packing Density	m^2/m^3		
Solid Heat Capacity @ STP	kJ/kg·K		

Crush Strength	kg_f		
Attrition Index	-		
Thermal Conductivity	W/(m·K)		
Adsorption			
Pressure	bar		
Temperature	°C		
Equilibrium Loading	gmol CO_2/kg		
Heat of Adsorption	kJ/gmol CO_2		
CO_2 Adsorption Kinetics	gmol/time		
Desorption			
Pressure	bar		
Temperature	°C		
Equilibrium Loading	gmol CO_2/kg		
Heat of Desorption	kJ/gmol CO_2		
CO_2 Desorption Kinetics	gmol/time		
Degradation	(% Capacity fade/cycle)		
Degradation Products and Concentrations (nitrosamines, aldehydes, …)	ppb		
Emissions: Criteria pollutants and capture system/media secondary emissions	ppb		
Characteristics of Previous Testing			
Location			
The following information should be provided for the longest steady-state duration test performed at bench scale or pilot scale			
Scale	tCO_2/year		
Duration of Long-Term Test (consecutive hours)	hrs		
CO_2 concentration in feed stream (e.g, flue gas, process stream)	%		
Carbon Capture Efficiency	%		
Cycle Time	Hr		
Sorbent Make-up rate	%/yr		
Details on sorbent reactivation or refreshing			
Heat Duty	KJ/Kg CO_2		
CO_2 Product Purity	Mol % dry		

CO_2 Product Oxygen Concentration	Mol% (or ppm)		

***Definitions for Table 2*:**
Attrition Index – For circulating sorbents, the attrition index includes the percentage and size of the fines generated.
STP – Standard Temperature and Pressure (15 °C, 1 atm)
Sorbent – Adsorbate-free (*i.e.* CO_2-free) and dry material as used in adsorption/desorption cycle.
Adsorption – The conditions of interest for adsorption are those that prevail at maximum sorbent loading. Measured data are preferable to estimated data.
Desorption – The conditions of interest for desorption are those that prevail at minimum sorbent loading. Operating pressure and temperature for the desorber/stripper are process dependent. Measured data are preferable to estimated data.
Pressure – The pressure of CO_2 in equilibrium with the sorbent. If the vapor phase is pure CO_2, this is the total pressure, and if it is a mixture of gases, this is the partial pressure of CO_2.
Packing Density – Ratio of the active sorbent area to the bulk sorbent volume.
Loading – The basis for CO_2 loading is mass of dry sorbent.
Kinetics – A characterization of the CO_2 adsorption/desorption trend with respect to time, as complete in the range of time as possible.
Cycle Time – time for entire absorption and regeneration cycle utilized during long term testing
Details on sorbent reactivation or refreshing – Include information about reactivation process and rates or sorbent replacement during the long-term test
CO_2 Product Purity – Average purity of the CO2 product from the capture system during the long-term testing
CO_2 Product Oxygen Concentration – Oxygen content of the CO2 produced during the long-term testing

Table 3. State-Point Data for Membrane Based Systems

	Units	Measured/ Estimated Performance	Projected Performance
Materials Properties			
Materials of Fabrication for Selective Layer			
Materials of Fabrication for Support Layer (if applicable)			
Nominal Thickness of Selective Layer (μm)			
Membrane Geometry			
Max Trans-Membrane Pressure	bar		
Hours tested without significant degradation			

Degradation Products and Concentrations			
Emissions: Criteria pollutants and capture system/media secondary emissions			
Membrane Performance			
Temperature	°C		
Pressure Normalized Flux for Permeate (CO_2)	GPU or equivalent		
CO_2/H_2O Selectivity	-		
CO_2/N_2 Selectivity	-		
Type of Measurement (Ideal or mixed gas)	-		
Proposed Module Design			
Flow Arrangement	-		
Packing Density	m^2/m^3		
Shell-Side Fluid	-		
Characteristics of Previous Testing			
Location			

The following information should be provided for the longest steady-state duration test performed at bench scale or pilot scale		
Scale	$tCO_2/yr.$	
CO_2 concentration in feed stream (e.g, flue gas, process stream)	%	
Duration of Long-Term Test (consecutive hours)	hrs	
Average CO_2 capture Efficiency	%	
Starting CO_2 Capture Efficiency	%	
Ending CO_2 Capture Efficiency	%	
Membrane Performance Degradation	%/year	
CO_2 Product Purity	Mol % dry	
CO_2 Product Oxygen Concentration	Mol % (or ppm)	
Membrane Feed Pressure*	psia	
Permeate Pressure*	psia	

***Definitions for Table 3*:**

Membrane Geometry – Flat discs or sheets, hollow fibers, tubes, etc.
Pressure Normalized Flux – For materials that display a linear dependence of flux on partial pressure differential, this is equivalent to the membrane's permeance.
GPU – Gas Permeation Unit, which is equivalent to 10^{-6} $cm^3/(cm^2 \cdot s \cdot cmHg)$ at 1 atm and 0 °C. For non-linear materials, the dimensional units reported shall be based on flux measured in $cm^3/(cm^2 \cdot s)$ (at 1 atm and 0 °C) with pressures measured in cm Hg. Note: 1 GPU = 3.3464×10^{-6} $kgmol/(m^2 \cdot s \cdot kPa)$ [SI units]
Type of Measurement – Either mixed or pure gas measurements; projected permeance and selectivities shall be for mixture of gases found in de-sulfurized flue gas.
Flow Arrangement – Typical gas-separation module designs include spiral-wound sheets, hollow-fiber bundles, shell-and-tube, and plate-and-frame, which result in either co-current, counter-current, cross-flow arrangements, or some complex combination of these.
Packing Density – Ratio of the active surface area of the membrane to the volume of the module.
Shell-Side Fluid – Either the permeate or retentate stream.
Starting CO_2 Capture Efficiency – Capture efficiency achieved in the first hour of long-term testing
Ending CO_2 Capture Efficiency – Capture efficiency achieved in the last hour of long-term testing.
CO_2 Product Purity – Average purity of the CO_2 product from the capture system during the long-term testing.
CO_2 Product Oxygen Concentration – Oxygen content of the CO_2 produced during the long-term testing.
Membrane Feed Pressure – Pressure of gas fed to the membrane for separation during the long-term test. *Repeat this parameter for each stage of membrane used during the long-term test.
Permeate Pressure – Pressure of the corresponding permeate of the membrane that accounts for the trans membrane pressure drop and any vacuum used. * Repeat this parameter for each stage of membrane used during the long-term test

Table 4. State-Point Data for Chemical Looping Based Hydrogen Production Systems

Characteristic	Current Value	Target Value
CO2 Capture Efficiency (%)		
CO2 Purity (%)		
Overall carrier circulation rate (lb/hr)		
Chemical looping carrier makeup rate (lb/hr)		
Chemical looping reducing material input rate (lb/hr)		
Chemical looping reduction material conversion rate (% of input)		
Energy input type		

Energy input rate		
Energy output type		
Energy output rate		

Chemical Looping Carrier Characteristics

For chemical looping systems, describe the carrier material in terms of type, source, particle size, particle density, reduction, and oxidation kinetics (qualitatively), and price.

Characteristic	Current Value	Target Value
Carrier type		
Carrier composition		
Particle size, mm (in)		
Particle density, kg/m^3 (lb/ft^3)		
Reduction and oxidation kinetics		
Degradation rate		
Price (delivered $/ton)		
Source		

Chemical Looping Reducing Material Characteristics

For chemical looping systems, describe the current and target values for the reducing materials.

Characteristic	Current Value	Target Value
Reducing material type		
Reducing material composition		
Particle size, mm (in)		
Particle density, kg/m^3 (lb/ft^3)		
Reduction and oxidation kinetics		
Conversion rate		
Price (delivered $/ton)		
Source		

Reactor Conditions and Configuration Features

The Recipient should duplicate this table for each reactor in the process. Chemical looping-specific oxidation and reduction reactor characteristics tables are provided below.

Chemical Looping Oxidation Reactor Characteristics	Current Value	Target Value
Reactor type		
Reactor geometry		
Reactor dimensions (ft)		
Inlet velocity (ft/s)		

Outlet velocity (ft/s)		
Temperature (°F)		
Pressure drop (psi)		
Input solids composition		
Input solids flow rate (lb/hr)		
Fluidized Bed Characteristics		
Carrier Fluidization Class at reactor conditions		
Type of fluidized bed regime		
Estimated bed structure		
Solids content, % of total solids volume: carrier, etc.		
Volume % solids in bed core region (fc,%)		
Volume of core region (δc,% of bed)		

Chemical Looping Reduction Reactor Characteristics	Current Value	Target Value
Reactor type		
Reactor geometry		
Reactor dimensions (ft)		
Inlet velocity (ft/s)		
Outlet velocity (ft/s)		
Temperature (°F)		
Pressure drop (psi)		
Input solids composition		
Input solids flow rate		
Fluidized Bed Characteristics		
Carrier Fluidization Class at reactor conditions		
Type of fluidized bed regime		
Estimated bed structure		
Solids content, % of total solids volume: carrier, etc.		
Volume % solids in bed core region (fc,%)		
Volume of core region (δc,% of bed)		

Table 5. State-Point Data for Hydrogen Production Systems

	Units	**Measured Performance** (at largest scale tested)
Materials Properties		
Feedstock Type		

Feedstock Feed Rate		
Test Rig Parameters		
Reactor Type		
Reactor Dimensions		
Reactor Geometry		
Energy Input Type		
Energy Input Rate		
Test Conditions		
Operating Temperature		
Operating Pressure		
Test Results		
Energy Output Type		
Energy Output Rate		
Hydrogen Output Rate		
Hydrogen Output Purity		
TEA/LCA Results		
Hydrogen Output Price		
Total CO2 Produced		
Net CO2 Emissions		

Appendix U – Process Model Requirements

Development and utilization of rigorous, first-principles, multi-scale, validated process models with uncertainty quantification (UQ)[38,39,40,41,42,43] to guide pilot scale test conditions through statistical design of experiments and robust optimization methodologies[44,45,46] and maximize learning from the proposed project is an essential element of the effort such that technical risk will be reduced for further scaleup and deployment. The applicant is encouraged to leverage existing open-source modeling tools such as those developed as part of the DOE/NETL-funded

38 Morgan JC, Bhattacharyya D, Tong C, Miller DC, 2015. Uncertainty quantification of property models: methodology and its application to CO2-loaded aqueous MEA solutions. AIChE J. 61 (6): 1822-1839. https://doi.org/10.1002/aic.14762

39 Morgan JC, Chinen AS, Omell B, Bhattacharyya D, Tong C, Miller DC, 2017. Thermodynamic modeling and uncertainty quantification of CO2-loaded aqueous MEA solutions. Chem. Eng. Sci. 168: 309-324. https://doi.org/10.1016/j.ces.2017.04.049

40 Akola, P., J. Eslick, D. Bhattacharyya and D. C. Miller (2021). Model Development, Validation, and Optimization of an MEA-Based Post-Combustion CO2 Capture Process under Part-Load and Variable Capture Operations. Industrial & Engineering Chemistry Research 60(14): 5176-5193, https://doi.org/10.1021/acs.iecr.0c05035

41 Chinen AS, Morgan JC, Omell B, Bhattacharyya D, Tong C, Miller DC, 2018. Development of a rigorous modeling framework for solvent-based CO2 capture. Part 1: hydraulic and mass transfer models and their uncertainty quantification. Ind. Eng. Chem. Res. 57: 10448-10463. https://doi.org/10.1021/acs.iecr.8b01471

42 Morgan JC, Chinen AS, Omell B, Bhattacharyya D, Tong C, Miller DC, Buschle B, Lucquiaud M, 2018. Development of a rigorous modeling framework for solvent-based CO2 capture. Part 2: steady-state validation and uncertainty quantification with pilot plant data. Ind. Eng. Chem. Res. 57: 10464-10481. https://doi.org/10.1021/acs.iecr.8b01472

43 Akula, P., A. Lee, J. Eslick, D. Bhattacharyya and D. C. Miller (2023). "A modified electrolyte non-random two-liquid model with analytical expression for excess enthalpy: Application to the MEA-H2O-CO2 system." AIChE Journal 69(1): e17935, https://doi.org/10.1002/aic.17935.

44 Morgan, J. C., A. S. Chinen, C. Anderson-Cook, C. Tong, J. Carroll, C. Saha, B. Omell, D. Bhattacharyya, M. Matuszewski, K. S. Bhat and D. C. Miller (2020). "Development of a framework for sequential Bayesian design of experiments: Application to a pilot-scale solvent-based CO2 capture process." Applied Energy 262: 114533, https://doi.org/10.1016/j.apenergy.2020.114533

45 Morgan, J.C., Omell, B., Matuszewski, M., Miller, D.C., Shah, M.I., Benquet, C., Knarvik, A.B.N., de Cazenove, T., Anderson-Cook, C.M., Ahmed, T., Tong, C., Ng, B., and Bhattacharyya, D., "Application of Sequential Design of Experiments (SDoE) to Large Pilot-Scaled Solvent-Based CO2 Capture Process at Technology Centre Mongstad (TCM) (March 24, 2021). Proceedings of the 15th Greenhouse Gas Control Technologies Conference 15-18 March 2021. https://dx.doi.org/10.2139/ssrn.3811695

46 N.M. Isenberg, P. Akula, J.C. Eslick, D. Bhattacharyya, D.C. Miller and C.E. Gounaris (2021). A Generalized Cutting-Set Approach for Nonlinear Robust Optimization in Process Systems Engineering Applications. AIChE Journal, 67(5):e17175. https://doi.org/10.1002/aic.17175

Carbon Capture Simulation Initiative (CCSI/CCSI2/IDAES)[47,48,49,50]. Process models will be subject to review via the substantial involvement clause to be included in the cooperative agreement for successful applicants. Recipients will not be required to deliver the actual process models, but will be required to provide briefings to DOE/NETL personnel demonstrating model validation across a wide range of testing conditions/characteristics. Based upon the review results, recipients will be required to update/improve models to achieve the objectives noted above.

The development of process models for specific technologies can be broken into several property and process submodels, which can be classified into physical properties, mass transfer, hydraulics, and kinetics. For example, for solvent systems many physical property models such as density, viscosity, surface tension, and thermal conductivity are generally represented as standalone correlations that are functions of temperature and composition. Thermodynamic models should be developed as integrated frameworks, to the extent possible, that incorporate all relevant properties, including vapor-liquid equilibria (VLE), heat of absorption, heat capacity, chemical equilibria, and pure component vapor pressure. Sorbent technologies typically require less integrated frameworks but should include models, as function of temperature and concentrations, for adsorption equilibrium, heat of adsorption for keys species (notably CO_2 and H_2O), heat capacity, kinetics, thermal conductivity, and density. Sorbent models also require hydraulics models that are typically found in literature, depending on the type of contactor being used in the process.

If data are unavailable for certain properties, correlations may be taken from the literature or commercial simulation packages and/or estimated using group properties methods, although these assumptions should be considered sources of uncertainty, and should be noted. These models should be developed and validated over the ranges of temperature and composition of interest, with data gaps identified. Furthermore, there likely will be limitations on some experimental data collection, whether it is limitations of experimental devices (e.g., wetted wall columns over the upper ranges of regeneration temperature ranges) or data that cannot be directly measured due to convoluted physical processes (e.g. physical diffusion of CO_2 in a chemical solvent, requiring a chemically inert surrogate). Where possible, parameters should be calibrated separately for the relevant sub-systems of interest (e.g., pure component, binary amine-H_2O, ternary amine-H_2O-CO_2). Sensitivity analysis and uncertainty quantification (UQ) methods can be employed to analyze the effect that individual submodels have on the overall

47 Lee, A., J. H. Ghouse, J. C. Eslick, C. D. Laird, J. D. Siirola, M. A. Zamarripa, D. Gunter, J. H. Shinn, A. W. Dowling, D. Bhattacharyya, L. T. Biegler, A. P. Burgard and D. C. Miller (2021). "The IDAES process modeling framework and model library—Flexibility for process simulation and optimization." Journal of Advanced Manufacturing and Processing 3(3): e10095, https://doi.org/10.1002/amp2.10095.
48 Miller, D. C., X. Sun, C. B. Storlie and D. Bhattacharyya (2015). "Using Advanced Modeling to Accelerate the Scale-Up of Carbon Capture Technologies." Power Engineering 119(6): 30-34
49 Miller, D. C., M. Syamlal, D. S. Mebane, C. B. Storlie, D. Bhattacharyya, N. Sahinidis, D. A. Agarwal, C. Tong, S. E. Zitney, A. Sarkar, X. Sun, S. Sundaresan, E. M. Ryan, D. Engel and C. Dale (2014). "Carbon Capture Simulation Initiative: A Case Study in Multiscale Modeling and New Challenges." Chemical and Biomolecular Engineering 5: 301-323, 10.1146/annurev-chembioeng-060713-040321
50 https://www.acceleratecarboncapture.org/

process performance and can be used to prioritize collection of additional data to fill gaps. However, care should be taken in the refinement of the parameters from the property submodels in that only data collected from the most direct, informative, experiment should be used. For example, packed column data for solvent-based processes should not be used to refine VLE thermodynamic parameters if direct VLE measurements can be taken.

As part of the FOA response, the applicant should provide information that describes process modeling efforts to date in a separate file (maximum 5 pages). To verify models for specific technologies, relevant property and process submodels should be described. A description of the data used to inform those models and a description of the range of conditions that data was collected (e.g., temperature, concentration). Furthermore, known data gaps should be identified, and what the expected impact on predictions of testing and scale-up of the proposed enabling technology would be. Finally, model validation should be described, providing descriptions of what scales the model has been validated (bench and pilot scale), and what model parameters/ correction factors, if any, were used as tuning parameters to improve the process model's predictiveness of the experiments.

Appendix V – Business Case Analysis– AOI-3H-a and AOI-3H-b only

The business case analysis demonstrates an understanding of the current and projected landscapes of the power production, hydrogen production and CO2 markets (if applicable) and the potential utilization of tax credits including their projected revenue and duration.

The first section of the business case analysis should identify the potential market size of the technology option proposed by the applicant. The analysis will contain a Business Case Analysis; Technical overview; Future deployment projection; and Quantification of potential benefits of the technology.

An outline of each of the four major pieces of the analysis are as follows:

Business Case Analysis

- A pro forma which quantifies the projected financial parameters such as operating costs, operating revenues, financing cash flows, EBITDA, tax credits/liabilities, and
- ROI over the project lifespan. The Business Case Analysis should also include a list of key economic/financial assumptions.

Technical overview

- Description of the technology and potential applicability across the relevant utility or industrial sector.

Future deployment projection

- Provide the potential deployment scale of the technology across the current and future related utility or industrial sector
- Identify and compare competing technology options
- Discussion of potential barriers to large scale deployment

Quantify Potential Benefits of the technology

- Provide estimates of the potential benefits of large-scale deployment in terms of metrics such as manufacturing jobs, revenue, emissions reductions, etc.

Appendix W - Preliminary FEED (pre-FEED) Study Guidance (AOI-3H-a and 3Hb)

The preliminary FEED study is an **AOI-3H-a and 3Hb** deliverable required from projects selected under this FOA. Activities include, but are not limited to, those listed below:

1. **Project Scope and Design** that includes deployment / business objectives and the summary of the proposed project. The roles and scope of work for the different parties involved in the project should be clearly delineated. The arrangement with the base plant during the planning/construction phase and capture plant operation phase should be made clear.

2. **Project Design Basis** including, but not limited to site characteristics and ambient conditions, fuel feedstock and flue gas characteristics, and host site environmental requirements. The design basis shall clearly identify all permits and environmental reviews necessary to initiate construction. All internal or corporate approvals required by the host site to initiate construction shall be identified. If after completing the pre-FEED, it is decided that a different plant configuration should be considered, and that the reported design is not viable, this information should be communicated clearly up front. If major design changes are required, this should be reflected in the project timeline, and a path forward clearly outlined.

3. **Engineering Design Package**. Design of the carbon capture system shall result in preliminary equipment sizing fully substantiated with kinetic, heat and mass transfer data, as well as justification for choice of materials of construction. The cost estimate shall include preparation of a capital cost estimate, including the cost of capture in $/tonne carbon oxides captured, levelized cost of electricity (LCOE) for AOI-3H-a and levelized cost of hydrogen (LCOH) for AOI-3H-b. The pre-FEED shall include, at a minimum: process flow diagrams; carbon capture process (and hydrogen production system, for AOI-3H-b) model scaled-up for the proposed facility; utility flow diagrams; piping and instrumentation diagrams; heat and material balances; plot plan; layout drawings; complete engineered process and utility equipment lists with all major equipment (e.g., for a solvent-based system: direct contact cooler, absorber, solvent heat exchangers, stripper, CO_2 compressors etc.) with specifications and sizing; single line diagrams for electrical; electrical equipment and motor schedules; vendor quotations; detailed project execution plans; resourcing and work force plans; a hazard and operability study (HAZOP) review; and a constructability review. The pre-FEED shall incorporate all engineering disciplines necessary to perform the final design and construction, which include, but are not limited: to process, civil, architectural, structural, mechanical, piping, electrical, and control systems engineering. A list of all referenced work should be provided.

Engineering design shall cover both the carbon capture system and balance-of-plant for AOI-3H-a and the entire hydrogen production system, including carbon capture and balance-of-plant for AOI3Hb. Balance-of-plant includes, but is not limited to, utilities such as compression, cooling water, water treatment, waste treatment, and the sources of energy, electricity, and/or steam, necessary to for the proposed systems. The latter may include integration of an external energy source (e.g., natural gas-fueled, solar, wind, geothermal) or integration of the carbon capture system into the existing plant. If the system is designed to purchase renewable electricity or to generate it on site, then the plant must include a method of energy storage or back-up power generation to supply electricity when renewable electricity is not available. If the system requires co-generation of power or steam for its operation, it must include carbon oxides capture, compression, and storage from both the base facility and co-generation plant.

For AOI-3H-a, the engineering design package should also cover the integration of the carbon capture process within the power plant facility, including but not limited to the following: novel approaches to recover waste heat from the facility and integrate it with the carbon capture system; and design of pollution control systems upstream of the carbon capture system. If multiple major emission sources exist at the facility, the applicant should describe whether aggregation of the sources into one stream, upstream of the carbon capture facility, is proposed. Details of the base plant should be highlighted before and after retrofit. This includes: the year the plant was built, expected plant life, and any plans for extension of plant life; plant gross and net power before and after retrofit; and the current and expected capacity factor and operational mode (base load or flexible operation).

For AOI-3H-b, the engineering design package should also cover the integration of the hydrogen production process with any carbon capture processes, , including but not limited to the following: novel approaches to recover waste heat from the facility and integrate it with the carbon capture system; and design of pollution control systems upstream of the carbon capture system. . If multiple major emission sources from the hydrogen production plant exist, the applicant should describe whether aggregation of the sources into one stream, upstream of the carbon capture facility, is proposed.

Successful projects will be required to submit the following documents, when complete:

i. **an initial engineering design package that includes, at a minimum, process flow diagrams, the results of the heat and material balances, sizing of the main pieces of equipment for the carbon capture plant and BOP based on a validated process model, and**
ii. **the final engineering design package, including project cost estimate prior to project completion.**

Design of the capture system shall support a capital cost estimate consistent with AACE (Association of the Advancement of Cost Engineering) Class 4 with an accuracy of -15% to -30% on the low side and +20% to +50% on the high side.

Pre-FEED Study – Requirements

The following is a list of content to be included in the pre-FEED study package developed by the end of the project for this FOA. Recipients are encouraged to include additional materials outside this list that resulted from the uniqueness of their respective project or the needs of the owner. Recipients are also encouraged to integrate pre-FEED study activities with relevant Community Benefits Plan (CBP) requirements and activities as appropriate for the project into an overall integrated project schedule. ALL sections of the report should be cross checked to ensure that the values agree between report(s). Missing appendices, section headings, and mislabeled figures should be avoided. Image quality should be checked; figures with unreadable text should not be included.

1. Project Background
    a. Discusses Project need or Deployment /Business Objective
    b. The executive summary should also include major aims and conclusions of each of the subsequent chapters.
2. Project Scope
    a. Provides a summary of the proposed project and how it will meet the objective
    b. Provides the system boundaries, or battery limits, of the proposed project
3. Project Design Basis
    a. Site Characteristics
        i. Location, topography, available land, transportation access, available utilities,
        ii. Social characterization, including regional analysis of communities and disadvantaged communities, and whether those communities rely on limited resources (e.g., water) that could be impacted by the project. This information should be consistent with the Initial CBP.
    b. Site Ambient Conditions
        i. Elevation, atmospheric pressure, temperature averages/extremes, prevailing wind, seismic data, air composition.
    c. Fuel Feedstock and Flue Gas Characteristics
        i. Design compositional analyses of the fuel (coal, natural gas, biomass, etc.)
        ii. Design compositional analyses of the flue gas (flow rate, composition, etc.)
    d. Environmental Requirements - as dictated by the authority(s) having jurisdiction (e.g., State DEP, EPA, etc.)
        i. Air emission permitting limitations and required control technologies
        ii. Water discharge permitting limitations and required control technologies
        iii. Waste disposal (e.g., coal ash, spent absorbents, etc.) permitting limitations and required control technologies
    e. Site Specific Design Considerations
        i. Flood plain, soil conditions, rainfall/snowfall criteria, building/enclosure permitting, noise regulations, local community requirements (plumes visibility), operational profile in terms of startups/shutdowns/reduced capacity operations for the proposed site
        f. Modularization Design Requirements
4. Basic contracting and purchasing strategy

a. Strategy for tracking cost and schedule performance such as cost performance indicators from an earned value management system.
b. Answers to the following questions should be provided:
    i. Who operates the capture plant?
    ii. What is the arrangement with the base plant?
    iii. Are personnel shared, or is the capture plant operated independently?
    iv. How is the base plant compensated for any derate or utilities provided to the capture plant?

5. Engineering Design Packages
    a. Process Engineering
        i. Process area descriptions
        ii. Block Flow Diagram (BFD), Process Flow Diagram (PFD), and Process & Instrumentation Diagram (P&ID) Minimum Stream Requirements:
        iii. Process simulation output and heat and material balances (H&MB)
        iv. For AOI-3H-a, carbon capture technology specific design details and for AOI-3H-b, hydrogen production and carbon capture technology specific design details
            1. Initial solvent fill, solvent make up rates, and reclamation requirements for solvent-based technologies; sorbent or membrane lifetime.
            2. Performance metrics:
                a. solvent systems: reboiler duty
                b. membrane systems: permeance, selectivity, vacuum pressure, differential pressure, membrane area
                c. sorbent systems: working capacity, selectivity, regeneration energy, vacuum pressure
        v. HAZOP/PHA documentation
        vi. Major Process Equipment specifications/data sheets including sizing
        vii. Equipment and instrumentation lists
            1. Key parameters and their value for equipment costing (i.e., height, diameter, heat duty, delta Temperature, power, materials of construction, etc.)
    b. Civil Engineering
    c. Structural Engineering
    d. Mechanical Engineering
        i. General site plan view(s)
        ii. 3-D model and/or equipment elevation sections & plan drawings
    e. Electrical Engineering
        i. Electrical load lists
    f. Instrumentation & Controls Engineering (System Integration)
        i. Control system architecture specification
        ii. Instrument/equipment lists and specifications
    j. Cybersecurity and associated information protection systems.
    k. Logistics
    l. Constructability
        i. Construction access
    m. Project Cost Estimate– Must specify year dollars basis and nominal vs real

i. Individual component capital cost (i.e., absorber, regenerator, etc.)
1. preferably includes costs for individual pieces of equipment, but at a minimum provides totals for the capture system, compression system, BOP and plant life extension costs (if applicable). Details regarding what is included in the capital cost estimate (labor, materials, equipment, contingency, engineering fees, delivery, etc. need to be provided).

ii. Breakdown of operating costs
1. Detailed accounting of O&M costs should be provided. This includes labor rates and personnel requirements, maintenance assumptions, consumable consumption rates and unit costs, waste generation rates and disposal costs, and power and fuel costs. Justifications for the unit costs should be provided where appropriate (e.g., power purchase agreements, waste classification as hazardous/nonhazardous etc.) Also, to the extent possible, please address:
    1. Labor quantity for construction and O&M
    2. Labor wages for construction and O&M
    3. Labor costs for construction and O&M
    4. Detailed description of data and methods used to produce estimates
    5. Project duration
    6. If possible (not required)
        1. Labor broken down by activity/component
        2. Labor broken down by position/skill
2. Auxiliary power requirements for different sub-systems of the capture system and balance of plant systems must be specified. An electrical load list should be provided.
3. The power source should also be specified (e.g., derate from the plant, purchased from grid, purchased from the plant, auxiliary CHP etc.).

iii. Owner's Costs

iv. Overall cost of capture ($/tonne of carbon oxides product) or cost of hydrogen
    i. Include analysis of effects of duty cycle, start-ups, shut-downs, partial load and transitions on overall capture rate and cost
        i. Based off of prior host site duty cycles, if available

v. Quantitative Risk Analysis and associated funding contingency requirements. Financial factors must be detailed. The methodology used to calculate the cost of carbon oxides capture must be clearly outlined. Requested details include:
1. Interest rate, project life, debt-equity arrangement, taxes, insurance, contingency and other cost escalation
2. Owner's cost calculation details
3. Annualization calculation details

i. Identification of the project critical path

Pre-FEED Study Checklist

Based on prior experience with pre-FEED study reporting, the following checklist is being provided to emphasize key piece of information that should be contained in the pre-FEED study

reports (as a minimum). The items shown in the checklist are all included in the above explanation but are being called out in this chart to increase the emphasis.

Category	Issue	Description	Location in Text/ Page Numbers
General	Potential changes to design	If after completing the pre-FEED it is decided that a different plant configuration should be considered, and that the reported design is not viable, this information should be communicated clearly up front. If major design changes are required, this should be reflected in the project timeline, and a path forward clearly outlined.	
	Definition of roles	The roles and scope of work for the different parties involved in the project should be clearly delineated. The arrangement with the base plant during the planning/construction phase and capture plant operation phase should be made clear.	
	Sources used	A list of sources for data should be provided.	
Performance	Base plant details	Details of the base plant should be highlighted before and after retrofit or for a new facility in AOI 3Hb. This includes: 1 - Year the plant was built, expected plant life, and any plans for extension of plant life 2 - Plant gross and net power before and after retrofit or construction in AOI-3H-b 3 - Current and expected capacity factor and operational mode (base load or flexible operation) [Design capacity factor and operational mode for AOI-3H-b]	

	Carbon Oxides capture process configuration	1 - The overall process flow diagram with main input and output streams should be highlighted. 2 - Detailed P&ID should be included. 3 - An equipment list with all major equipment (direct contact cooler, absorber, solvent heat exchangers, stripper, carbon oxides compressors etc.) specifications and sizing should be provided.	
	Capture system details	Capture technology details allowing comparison with other technologies is requested. This includes: 1 - Initial solvent fill, solvent make up rates, and reclamation requirements for solvent-based technologies; sorbent or membrane lifetime. 2 - Performance metrics: i - solvent systems: reboiler duty ii - membrane systems: permeance, selectivity and vacuum pressure, differential pressure, membrane area iii - sorbent systems: working capacity, selectivity, regeneration energy, vacuum pressure	
	Hydrogen Production System Details (If applicable)	Hydrogen production technology details allowing comparison with other technologies is requested. This includes: 1-Feedstock type, Feed rate, Reactor Type, Reactor Geometry and dimensions, Operating Temperature and Pressure 2- Performance metrics: Energy input type and rate, Energy output type and rate, Hydrogen output rate, purity and cost	

	Compression system details	Compression technology details allowing comparison with other technologies is requested. This includes: 1 - Compressor type 2 - Number of stages 3 - Electricity or steam requirement details 4 - Output pressure	
	Stream tables	Energy and mass balance details should be provided for all process streams.	
	Steam requirement	The source, quality, and quantity of steam required by the process must be specified for each application	
	Auxiliary power	1 - Auxiliary power requirements for different sub-systems of the hydrogen production or carbon capture system and balance of plant systems must be specified. An electrical load list should be provided. 2 - The power source should also be specified (e.g., derate from the plant, purchased from grid, purchased from the plant, auxiliary CHP etc.).	

	Justification of design	Justification for all major design decisions should be provided. This includes: 1 - results from any case studies performed when deciding on the specific configuration 2 - system modeling details including, model basis and validation, system modeling results, and justification for any design decisions that deviate from the modeled system 3 - justification for carbon oxides product stream purity and pressure	
Cost	Dollars	The year of dollar must be provided and nominal vs. real dollars specified for clarity.	
	Cost details	Detailed costs should be provided. This includes: 1 - Capital cost: preferably includes costs for individual pieces of equipment, but at a minimum provides totals for the hydrogen production system (AOI 3Hb only), capture system, compression system, BOP and plant life extension costs (if applicable). Details regarding what is included in the capital cost estimate (labor, materials equipment, contingency, engineering fees, delivery, etc. need to be provided). 2 - O&M costs: a detailed accounting of O&M costs should be provided. This includes labor rates and personnel requirements, maintenance assumptions, consumable consumption rates and unit costs, waste generation rates and disposal costs, and power and fuel costs. Justifications for the unit costs should be provided where appropriate (e.g., power purchase	

		agreements, waste classification as hazardous/nonhazardous etc.) 3 - Owner's cost 4 - Cost of carbon oxides capture 5 – Cost of hydrogen production (AOI 3Hb only)	
	Costing methodology	Financial factors must be detailed. The methodology used to calculate the cost of carbon oxides capture or hydrogen production must be clearly outlined. Requested details include: 1 - interest rate, project life, debt-equity arrangement, taxes, insurance, contingency and other cost escalation 2 - owner's cost calculation details 3 - Annualization calculation details	
Reporting	Report organization	The FOA gives an outline for important sections to be included in the pre-FEED report; the executive summary should also include major aims and conclusions of each of the subsequent chapters.	
	Quality control	There should be no inconsistencies in reported values for streams and costs etc., in different sections of the report. Missing appendices, section headings, and mislabeled figures should be avoided. Image quality should be checked; figures with unreadable text should not be included.	

Pre-FEED Study Value Template

Reported quantities can be adjusted based upon the Area of interest or capture technology.

Checklist Values			
Parameter	**Units**	**Value**	**Pages in Text Discussing Parameter**
Base Plant, pre-retrofit			
Gross Power, pre-retrofit	MW		
Auxiliary Load, pre-retrofit	MW		
Net Power, pre-retrofit	MW		
Steam to LP steam turbine	lb/hr		
	psia		
Flue Gas, pre-retrofit	lb/hr		
	F		
	psia		
CO_2 Flow Rate in Flue Gas, pre-retrofit	lb/hr		
	mol% CO_2 or wt% CO_2		
Capacity Factor	%		
Startup Time	min		
Turndown Ability	%		
Base Plant + Capture			
Gross Power, post-retrofit	MW		
Auxiliary Load of Base Plant	MW		
Auxiliary Load of CO_2 Capture Island	MW		
Auxiliary Load of CO_2 Compression	MW		
Net Power, post-retrofit	MW		
Steam to LP steam turbine	lb/hr		
	psia		
Steam to Capture System	lb/hr		
	psia		
Flue Gas	lb/hr		
	F		
	psia		
Capacity Factor	%		
Startup Time	min		
Turndown Ability	%		

CO_2 Capture Plant - Solvent Systems			
Percent of Flue Gas Sent to Capture Facility	%		
CO_2 Capture Rate	%		
Captured CO_2 Stream Leaving the Regenerator	lb/hr		
	F		
	psia		
	mol % CO_2		
CO_2 Product	lb/hr		
	F		
	psia		
	mol % CO_2		
Water Consumption of the Capture Island Facility	lb/hr		
Initial Solvent Fill	tons		
Solvent Make-up Rate	tons/yr		
Caustic Initial Fill for DCC	tons		
Caustic Make-up Rate for DCC	tons/yr		
Caustic Content in Solution	%		
Costs - Solvent Systems			
Dollar Year Basis	Year		
CO_2 Removal System			
Equipment	$		
Material	$		
Labor	$		
Engineering Contracting	$		
Process Contingencies	$		
Project Contingencies	$		
CO_2 Compression System			
Equipment	$		
Material	$		
Labor	$		
Engineering Contracting	$		
Process Contingencies	$		
Project Contingencies	$		
BOP Modifications			
Equipment	$		
Material	$		
Labor	$		

Engineering Contracting	$		
Process Contingencies	$		
Project Contingencies	$		
Initial Solvent Fill	$		
Solvent Make-up	$/yr		
Caustic Initial Fill for DCC	$		
Caustic Make-up for DCC	$/yr		
Waste/Hazardous Waste	$/yr		
CO_2 Capture Plant - Membrane Systems			
Percent of Flue Gas Sent to Capture Facility	%		
CO_2 Capture Rate, total	%		
CO_2 Capture Rate per membrane section	%		
CO_2 Purity in Each Permeate Section	mol%		
Captured CO_2 Stream Leaving the Reboiler	lb/hr		
	F		
	psia		
	mol % CO_2		
CO_2 Product	lb/hr		
	F		
	psia		
	mol % CO_2		
Water Consumption of the Capture Island Facility	lb/hr		
Total Number of Membranes	#		
Total Contact Area of the Membranes	ft2		
Membrane Permeance	GPU		
Membrane Selectivity	CO_2/N_2		
Caustic Initial Fill for DCC	tons		
Caustic Make-up Rate for DCC	tons/yr		
Caustic mol Percent in Solution	%		
Costs - Membrane Systems			
Year Dollar Basis	Date		
CO_2 Removal System			
Equipment	$		
Material	$		

Labor	$		
Engineering Contracting	$		
Process Contingencies	$		
Project Contingencies	$		
CO_2 Compression System			
Equipment	$		
Material	$		
Labor	$		
Engineering Contracting	$		
Process Contingencies	$		
Project Contingencies	$		
BOP Modifications			
Equipment	$		
Material	$		
Labor	$		
Engineering Contracting	$		
Process Contingencies	$		
Project Contingencies	$		
Cost per Membrane Unit Area	$/ft^2		
Cost per Membrane Skid	$		
Membrane Replacement Costs	$/yr		
Membrane Average Lifetime	yr		
Caustic Initial Fill for DCC	$		
Caustic Make-up for DCC	$/yr		
Waste/Hazardous Waste	$/yr		

Appendix X – Business Case Analysis (AOI-4A)

The business case analysis should demonstrate an understanding of the current and projected commercial viability of the proposed multimodal transfer facility. The analysis should describe the projected and intended use for the multimodal transfer facility over the next 30 years including types of CO_2 sources and sinks in the present and future that will be available to utilize the transfer facility. The analysis must also clearly state whether the project will be an open access or common carrier infrastructure to all interested shippers and has considered capacity for future CO_2 sources.

The analysis will contain five major components: Business Case Analysis, technical overview, market analysis, future deployment projection, and quantification of potential benefits of the technology. These components are described below:

Business Case Analysis

- A pro forma which quantifies the projected financial parameters such as operating costs, operating revenues, financing cash flows, earnings before interest, taxes, depreciation, and amortization (EBITDA), tax credits and liabilities, and Return on Investment (ROI) over the project lifespan. The Business Case Analysis should also include a list of key economic and financial assumptions.

Technical Overview

- Description of how the facility will aggregate CO_2 from various sources and perform the necessary operations to continue transporting the CO_2 to its delivery point(s)

Market Analysis

- Description of the CO_2 sources, CO_2 conversion options, and/or CO_2 geologic storage locations, and transport routes within the region of interest of the Pre-FEED study.
- Analysis of applicability for co-location of this technology with other clean energy applications.
- Discussion of the potential utilization of tax credits and other incentives, including projected revenue and duration.
- Discussion of potential financing structures, partnerships, and owner/operator strategy for development and operation of the facility

Future Deployment Projection

- Discuss the potential deployment scale of multimodal transfer facility with consideration of the current and future CO_2 sources, CO_2 conversion, and/or CO_2 geologic storage locations.
- Identify and compare competing technology options and/or competing transportation modes.

- Discussion of potential barriers to large scale deployment.

Quantify Potential Benefits of the Multimodal Transfer Facility

- Provide estimates of the potential benefits of large-scale deployment in terms of quantifiable metrics. This may include, but is not limited to, temporary and permanent jobs, revenue, emissions reductions, community impacts, and environmental and energy justice impacts.

Appendix Y – Regulatory Plan Analysis (AOI-4A)

Applicants must submit a regulatory plan that demonstrates how the deployment of the proposed multimodal transfer facility will meet or exceed local, state, and federal regulatory requirements. The regulatory plan shall identify the permits and regulatory approvals needed to construct and operate the proposed multimodal transfer facility. Successful Applicants will demonstrate the ability of a plan to exceed the minimum health, safety, environment, and regulatory requirements. The Regulatory Plan shall identify if community and stakeholder support has been obtained or opposition has been received by the Applicant. If awarded, Applicants must implement, evaluate, and update this plan throughout the life of the project. In addition, successful Applicants will be required to report on regulatory approval progress and outcomes throughout the project lifecycle and the final report at the direction of DOE.

The Applicant's Regulatory Plan must include the following elements and may include additional elements, as appropriate:

1. **Background.** A description of prior and ongoing efforts by members of the project team to engage regulators relevant to this proposed project. This may include existing and historic regulatory proceedings, as well as granted or denied regulatory approvals. For ongoing proceedings, the Regulatory Plan will include the regulatory request at issue (including legal criteria) and estimated timeline for the process.

2. **Adverse Parties.** Include an assessment of existing community support for and/or opposition to the project. Identify and provide a brief summary of any parties or groups that have been adverse or demonstrated opposition to the proposed project in prior or ongoing regulatory proceedings.

3. **Regulatory Plan Analysis Summary.** Provide a description of methods utilized to:
    a. Identify regulatory requirements and proceedings; and
    b. Collect, analyze, and evaluate community perspectives and viewpoints.

4. **Engagement Methods and Timeline.** Applicants should develop:
    a. A permitting list with review and approval agencies, including estimated timeline for submitting permit applications and obtaining identified permits; and
    b. A plan for engaging regulators, with objectives, that is appropriately aligned to project stage. This should include a description of specific methods that will be used to engage regulators. Engagement methods may include activities like pre-application presentations to regulators. Engagement objectives may include learning about regulators' policy concerns and legal requirements, seeking input, addressing input and concerns, and providing information.

The Applicant must indicate that the plan implementation will begin no later than 90 days after project award.

5. **Consent-Based Siting Statement.** The statement should include discussion of whether eminent domain is legally permissible in the jurisdiction of the proposed project. If eminent domain is allowed under law, the Applicant must:
    a. Indicate if they intend to pursue the use of eminent domain.
    b. Discuss options that may or have been explored to avoid the use of eminent domain.
    c. Explain how eminent domain, if used, may be consistent with two-way engagement. The applicant should consider how they plan to follow the consent-based siting considerations in Appendix M.

6. **Project Agreements Statement.** Provide a brief statement describing any plans to negotiate a Community Benefits Agreement, Good Neighbor Agreement, or similar agreement, and whether those agreements will be used to seek regulatory approval.

7. **Resource Summary.** Provide a summary of project resources dedicated to implementing the plan. The summary should include staff resources (quantity, total work hours required, and experience), facilities, capabilities, and budget (both federal and cost share) that will support implementing the plan.

Future Work. Include a description of potential regulatory activities for future work either under DOE awards or the lifecycle of the multimodal transfer facility.