FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

CLEAN HYDROGEN PRODUCTION, STORAGE, TRANSPORT AND UTILIZATION TO ENABLE A NET-ZERO CARBON ECONOMY

Funding Opportunity Announcement (FOA) Number: DE-FOA-0002400
FOA Type: MODIFICATION 0000010
Assistance Listing Number: 81.089 Fossil Energy Research and Development

FOA Amendment Issue Date:	09/12/2023
Submission Deadline for Full Applications:	11/14/2023 11:59:59 PM ET
Expected Date for Selection Notifications:	March 2024
Expected Date for Award:	July 2024

Modifications

Modifications to the Funding Opportunity Announcement are highlighted in the body of the FOA as follows. Changes from the previous modification are highlighted in green.

Mod. No.	Date	Description of Modification
000001	01/25/2021	The purpose of this modification is to revise Appendix S.1 – Basis for Techno-Economic Analysis, as reflected on Page 125 of the FOA.
000002	01/25/2021	The purpose of this modification is to release the revised Funding Opportunity Announcement document for Modification 000001 in FedConnect. (No highlighted changes in the body of the FOA)
000003	02/04/2021	The purpose of this modification is to incorporate the FOA Budget Justification File for projects longer than 3 years as an Attachment in FedConnect. (No highlighted changes in the body of the FOA)
0000004	02/18/2021	The purpose of this modification is to extend the application due date from 03/01/2021 at 11:59:59 ET to 03/08/2021 at 11:59:59 ET
0000005	02/07/2022	The purpose of this modification is to solicit applications for Areas of Interest, 1, 2a, 2b, 8a and 8b; update the FOA title, update the Funding Opportunity Description section and incorporate the requirement for an Environmental Justice Questionnaire to address current administration priorities, revise the Merit Review Criteria, incorporate information on U.S. Competitiveness and the DOE-approved Determination of Exceptional Circumstances (DEC), and update the Appendices.
0000006	02/07/2022	The purpose of this modification is to remove the DOE disclaimer language and to attach the budget justification file. The highlights from modification 0000005 remain.
0000007	03/18/2022	The purpose of this modification is to extend the deadline to submit applications from 3/23/2022 to 3/30/2022.
0000008	08/26/2022	The purpose of this modification is to solicit applications for Areas of Interest 4, 14a, 14b, 15, and 16, update authorizing statutes, update the cost share requirement, revise the Merit Review Criteria, and incorporate application requirements related to Societal Considerations and Impact.
0000009	10/12/2022	The purpose of this modification is to extend the deadline to submit applications from 10/25/2022 to 11/08/2022. The highlights from modification 0000008 remain.
0000010	09/12/2023	The purpose of this modification is to add and solicit applications for Areas of Interest 18, 19, & 20; edit Merit Review Criterion (MRC) 4 and MRC weighting; update Community Benefit Plan language throughout; update FFRDC/NL maximum effort; add Transparency of Foreign Connections and Potentially Duplicative Funding application requirements and Affirmative Action & Pay Transparency Requirements and Foreign Collaboration Considerations terms; and update other FOA terms and requirements to the latest versions.

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** Applicants must register with SAM at https://www.sam.gov/ prior to submitting an application in response to this FOA (unless the Applicant is exempt from those requirements under 2 CFR 25.110). Designating an Electronic Business Point of Contact (EBiz POC) and obtaining a special password called an MPIN are important steps in SAM registration. Failure to register with SAM will prevent your organization from applying through Grants.gov. The Applicant must maintain an active SAM registration with current information at all times during which it has an active Federal award or application under consideration. More information about SAM registration for Applicants is found at:
  https://www.fsd.gov/gsafsd_sp?id=gsafsd_kb_articles&sys_id=650d493e1bab7c105465eaccac4bcbcb.

  NOTE: If clicking the SAM links do not work, please copy and paste the link into your browser.

  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: Sub-awardees/Sub-recipients at all tiers must also obtain an UEI from the SAM and provide the UEI to the Prime Recipient before the sub-award can be issued.

- **Grants.gov** - Applicants must register with Grants.gov and set up your WorkSpace. You cannot submit an application through Grants.gov unless you are registered. Please read the registration requirements carefully and start the process immediately.

1) The Authorized Organizational Representative (AOR) must register at: https://apply07.grants.gov/apply/OrcRegister
2) An email is sent to the E-Business (E-Biz) POC listed in SAM. The E-Biz POC must approve the AOR registration using their MPIN from their SAM registration.

More information about the registration steps for Grants.gov is provided at:
https://www.grants.gov/web/grants/Applicants/registration.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://www.grants.gov/web/grants/Applicants/registration/add-profile.html
- *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.**

  For more detailed instructions about creating a profile on Grants.gov, refer to: https://www.grants.gov/web/grants/Applicants/registration/authorize-roles.html

  To track your role request, refer to: https://www.grants.gov/web/grants/Applicants/registration/track-role-status.html

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: www.fedconnect.net.

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

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I. Funding Opportunity Description

A. Authorizing Statutes

The programmatic authorizing statutes are:

- Public Law (PL) 95-91, DOE Organization Act, 42 U.S.C. § 7101., et seq. (Public Law 95-91), as amended
- Energy Act of 2020 (Division Z of the "Consolidated Appropriations Act, 2021'')
- PL 109-58, Energy Policy Act 2005, 42 U.S.C. § 15801., et seq. (Public Law 109-58) as amended, TITLE IX, Subtitle F, Sec. 961
- PL 104-271 Hydrogen Future Act of 1996
- PL 110-140 Energy Independence and Security Act of 2007

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

Advances in hydrogen technologies capable of improving performance, reliability, and flexibility of existing and novel methods to produce/transport/store/use hydrogen will enable the United States to greatly reduce its carbon footprint associated with energy use, supporting administration goals to reduce greenhouse gas (GHG) pollution by 2030 and to achieve economy-wide net-zero emissions by 2050.

Traditional large-scale hydrogen production approaches will face challenges in the U.S. marketplace to realize a net-zero carbon future. Technologies that use carbonaceous feedstock routes to hydrogen need technological advancements to improve their GHG emission performance. Hydrogen production from municipal solid wastes (MSWs), legacy coal wastes[1] (i.e., material taken from existing refuse stockpiles that are not associated with ongoing mining operations), and waste plastics have the potential for additional environmental and public safety benefits by diverting unrecyclable wastes from landfills or from incineration. Advancements may enable utilization of legacy coal waste and other impounded waste materials, thus relieving a burden faced by local communities and promoting environmental justice. Judicious use of biomass with incorporation of carbon capture and storage technologies is essential to enable net-zero life cycle carbon emissions.

[1] For this entire document, "legacy coal waste" refers to material sourced from existing refuse stockpiles that are not associated with ongoing mining operations that are producing additional coal wastes.

The leveraging of gasification approaches offers opportunities to advance environmental justice because gasification technology can convert varied waste feedstock materials into clean energy with superior environmental performance, including the attainment of net-zero carbon emissions. Communities burdened with landfills and waste dumps will benefit via decreased volume of wastes sent to landfills and the creation of disposition pathways for certain wastes. Locating waste-to-energy plants that produce clean hydrogen in communities that have been historically marginalized and overburdened by pollution and underinvestment could lead to creation of valuable jobs, investment in water and wastewater infrastructure, and economic opportunity.

The societal push toward net-zero carbon power sources in the United States, consistent with Executive Order (EO) 14008,2 encourages the continued development of hydrogen turbines and solid oxide fuel cells (SOFCs) by the U.S. Department of Energy's (DOE) Office of Fossil Energy and Carbon Management (FECM), in addition to other hydrogen and fuel cell technologies pursued by other DOE offices. Expanded use of these efficient hydrogen conversion technologies also necessitates the ramp-up of hydrogen production through more efficient and cost-effective methods, such as reversible solid oxide fuel cells (RSOFCs) or solid oxide electrolysis cells (SOECs), in coordination with the Hydrogen and Fuel Cell Technologies Office (HFTO) within DOE's Office of Energy Efficiency and Renewable Energy (EERE). Developing more efficient and reduced-cost pathways supports DOE's Hydrogen Shot Initiative, which seeks to reduce the cost of clean hydrogen by 80% to $1 per 1 kilogram in one decade. With involvement of multiple concerned DOE offices, technologies for advanced hydrogen production methods identified here will be improved and matured to make progress toward the ambitious Hydrogen Shot goals.

To realize the widespread contribution of clean hydrogen into a carbon-neutral economy, significant improvements must be made to ensure that storage and transportation of hydrogen is both safe and economically viable.

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,

[2] Executive Order 14008 of January 27, 2021.

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 HH** for more information on the R&D Community Benefits Plan content requirements.

C. Objectives/Areas of Interest

This FOA will develop technologies enabling clean hydrogen production, transport, storage, and use in the energy sector, including electricity, heat, transportation, and industrial use. The development of these technologies supports the ambitious goals for a carbon-neutral economy by 2050, a carbon-neutral power sector by 2035, and a 50% reduction from 2005 levels in economy-wide net GHG pollution by 2030. Significant advances in technology, economics, and infrastructure are needed in Areas of Interest (AOIs) under the following seven main categories, with the noted objectives:

1. Life Cycle Net-Zero and Net-Negative Carbon-Emitting Technologies for Clean Hydrogen Production from Modular Gasification—The objective is to advance gasification technologies by extending hydrogen generation capabilities into use of feed materials comprised mainly of biomass, waste plastics, MSW, other wastes, and mixtures thereof to facilitate clean energy and climate goals.

2. Solid Oxide Electrolysis Cell Development—The objective is to develop new or modified materials for SOECs and improve understanding of degradation mechanisms in SOECs for efficient and cost-effective production of hydrogen. This work will be coordinated with HFTO within EERE, particularly on SOECs as part of the hydrogenNEW consortium or hydrogen@scale FOA in 2022.

3. Carbon Capture—The objective is to complete the initial design and front-end engineering design (FEED) studies of a commercial-scale, carbon capture, utilization, and storage (CCUS) system that separates and stores more than 100,000 tonnes/year net carbon dioxide (CO2) of 95% purity, with 95% carbon capture efficiency, from a steam methane reforming (SMR) or autothermal reforming (ATR) plant producing 99.97% hydrogen from natural gas.

4. Advanced Turbines—The objective is to advance the performance of gas turbine combustion systems fueled with high-purity hydrogen, hydrogen and natural gas mixtures, and other carbon-neutral fuels (e.g., ammonia). An additional objective is to demonstrate a hydrogen-fueled rotating detonation engine in a gas turbine.

5. Natural Gas-Based Hydrogen Production—The objective is to develop transformative natural gas decarbonization technologies to produce net-zero or net-negative carbon hydrogen to meet needs of future hydrogen markets.

6. Hydrogen Pipeline Infrastructure—The objective is to develop technologies that improve the cost and performance (e.g., resiliency, reliability, safety, integrity) of hydrogen transportation infrastructure, including pipelines, hydrogen separation technologies, and compression stations, with an emphasis on mitigating emissions across natural gas-hydrogen value chains.

7. Subsurface Hydrogen Storage—The objective is to develop technologies to improve the cost and performance (efficiency, safety, integrity) of subsurface hydrogen storage.

This FOA is broad in scope and will be used to solicit research and development (R&D) through fiscal year 2024 for specific areas of interest (AOIs) aligned with the above seven general program areas. The AOIs are summarized in the table below with detailed information contained in the referenced Appendices attached to the FOA. In its original issuance, the FOA defined several AOIs; however, due to funding limitations, applications were only solicited for a subset. Two subsequent amendments solicited applications for additional portions of the originally unfunded AOIs. The FOA amendment currently being authorized will fund three newly added AOIs. The three AOIs funded under the current amendment fall within the first category, entitled "Life Cycle Net-Zero and Net-Negative Carbon-Emitting Technologies for Clean Hydrogen Production from Modular Gasification."

As program funds become available, it is anticipated that the FOA may be amended to solicit applications for some or all of the remaining AOIs, or under newly defined additional AOIs. Activities will be coordinated with work within EERE and other offices to avoid duplication, leverage resources, and maximize effective use of Federal funding.

Applications are only being accepted for AOIs that are currently funded. Applications will no longer be accepted once the submission deadline for the specified AOI has passed.

Appendix	AOI	AOI Title	Issue Date For AOI	FOA Modification	Total DOE Funds Available ($K)	Anticipated No. of Awards	Estimated Period of Performance	Application Submission Deadline
A	1	Clean Hydrogen Cost Reductions via Process Intensification & Modularization for Hydrogen Shot **-- Previously Issued –** **Not accepting new applications.**	2/07/2022	0000005	**	**	24 months (Single Phase/ Single Budget Period)	3/23/2022
B	2a	Clean Hydrogen from High-Volume Waste Materials and Biomass **-- Previously Issued –**	2/07/2022	0000005	**	**	24 months (Single Phase/ Single Budget Period)	3/23/2022

		Not accepting new applications.						
C	2b	Sensors & Controls for Co-gasification of Waste Plastics in Production of Hydrogen with Carbon Capture **-- Previously Issued –** **Not accepting new applications.**	2/07/2022	0000005	**	**	24 months (Single Phase/ Single Budget Period)	3/23/2022
	AOI 2 Subtotal				**	**		**
D	3	Novel High-Purity Hydrogen Separations			N/A*			
E	4	Advanced Air Separation for Low-Cost H_2 Production via Modular Gasification **-- Previously Issued –** **Not accepting new applications.**	08/26/2022	0000008	**	4	24 months (Single Phase/ Single Budget Period)	11/08/2022
F	5	Solid Oxide Electrolysis Cell (SOEC) Technology Development for Hydrogen Production **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	24 months (Single Phase/ Single Budget Period)	3/8/2021
G	6	SOFC and SOEC Component Materials Thermodynamic Database			N/A*			
H	7	Initial Engineering Design of Advanced CO_2 Capture from Hydrogen Production						
	7a	Advanced CCUS Systems from Steam Methane Reforming Plants **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	18 months (Single Phase/ Single Budget Period)	3/8/2021
	7b	Advanced CCUS systems from Autothermal Methane Reforming Plants **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	18 months (Single Phase/ Single Budget Period)	3/8/2021
		AOI 7 Subtotal			**	**		**
I	8	Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Industrial Facilities Producing H_2 from Natural Gas						
	8a	Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Steam Methane Reforming (SMR) Facilities Producing H_2 from Natural Gas **-- Previously Issued –** **Not accepting new applications.**	2/07/2022	0000005	**	**	18 months (Single Phase/ Single Budget Period)	3/23/2022
	8b	Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Autothermal Reforming (ATR) Facilities Producing H_2 from Natural Gas **-- Previously Issued –** **Not accepting new applications.**	2/07/2022	0000005	**	**	18 months (Single Phase/ Single Budget Period)	3/23/2022
		AOI 8 Subtotal			**	**		**
J	9	Hydrogen Combustion Systems for Gas Turbines						
	9a	F-Class **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	48 months (Multiple	3/8/2021

							Budget Periods)	
	9b	Aeroderivative Class **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	48 months (Multiple Budget Periods)	3/8/2021
	9c	Industrial Class **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	48 months (Multiple Budget Periods)	3/8/2021
		AOI 9 Subtotal			**	**		**
K	10	Pre-commercial Testing of a Hydrogen Fueled Gas Turbine			N/A*			
L	11	Ammonia Combustion Systems for Gas Turbines **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	48 months (Multiple Budget Periods)	3/8/2021
M	12	Demonstration of a Rotating Detonation Engine in a Gas Turbine **-- Previously Issued –** **Not accepting new applications.**	1/15/2021	Initial	**	**	48 months (Multiple Budget Periods)	3/8/2021
N	13	Data Gathering and Baseline Assessment for Regional Hydrogen Hubs			N/A*			
O	14	Clean Hydrogen Production and Infrastructure for Natural Gas Decarbonization						
	14a	Methane pyrolysis/decomposition, in situ conversion, or cyclical chemical looping reforming. **-- Previously Issued –** **Not accepting new applications.**	8/26/2022	0000008	**	**	24 months (Multiple Budget Periods)	11/08/2022
	14b	Hydrogen Production from Produced Water **-- Previously Issued –** **Not accepting new applications.**	8/26/2022	0000008	**	**	24 months (Multiple Budget Periods)	11/08/2022
	14c	Additional Transformational Clean Hydrogen Production Methods			N/A*			
		AOI 14 Subtotal			**	**		**
P	15	Technologies for Enabling the Safe and Efficient Transportation of Hydrogen Within the U.S. Natural Gas Pipeline System **-- Previously Issued –** **Not accepting new applications.**	8/26/2022	0000008	**	**	24 months (Multiple Budget Periods)	11/08/2022
Q	16	Fundamental Research to Enable High Volume, Long-term Subsurface Hydrogen Storage **-- Previously Issued –** **Not accepting new applications.**	8/16/2022	0000008	**	**	24 months (Multiple Budget Periods)	11/08/2022
R	17	Hydrogen Compression for Pipeline Transportation and Subsurface Storage			N/A*			
S	18	Maturation of Technologies for Gasification-Based Clean Hydrogen Systems						
	18a	Oxygen-Generating Component/ Air Separation Unit	09/12/2023	0000010	12,000	2	24 Months (Single Phase/	11/14/2023

							Single Budget Period)	
	18b	Feedstock Delivery Component	09/12/2023	0000010	7,000	2	24 Months (Single Phase/ Single Budget Period)	11/14/2023
		AOI 18 Subtotal	09/12/2023		19,000			11/14/2023
T	19	Advanced Sensors to Enable Gasification to Provide Clean Hydrogen Meeting Hydrogen-Shot Cost Parameters	09/12/2023	0000010	1,500	3	24 Months (Single Phase/ Single Budget Period)	11/14/2023
U	20	Digital Twins for Advanced Monitoring, Detection, and Security for Integrated Hydrogen-Based Systems with Carbon Capture	09/12/2023	0000010	2,100	3	24 Months (Single Phase/ Single Budget Period)	11/14/2023
				Modification 0000010 Totals	**22,600**	**Up to 10**		

*Applications are not being solicited at this time for AOIs designated with N/A in the Total Amount of DOE Funds Available Column.
**AOI has been previously issued. No new applications will be accepted at this time.

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 Responsiveness Criteria):

- Submissions that fall outside the technical parameters specified in Section I.C of the FOA.
- Submissions that include proposed R&D for more than one AOI.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates the laws of thermodynamics).
- Submissions that describe a technology but do not propose a R&D plan that allows DOE to evaluate the submission under the applicable merit review criteria provided in Section V of the FOA.

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 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 listed in the following table. Some areas of interest are unfunded in the current FOA. Those unfunded areas of interest, plus newly defined areas of interest, could be funded with future appropriations to various programs, if available, in which case the FOA document will be amended as appropriate.

Areas of Interest & Cost Share

Topic Area/Area of Interest	Estimated Federal Funding $K	Anticipated No. of Awards	Anticipated Individual Award Size			Maximum DOE Share of Awards $K
			DOE Share* $K/%	Cost Share ** $K/%	Total $K	
1	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
2a	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
2b	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
3	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
4	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
5	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
6	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
7a	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
7b	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
8a	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
8b	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
9a	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
9b	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
9c	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
10	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
11	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
12	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
13	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
14a	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
14b	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
15	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
16	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
17	N/A***	N/A***	N/A***	N/A***	N/A***	N/A***
18a	12,000	Up to 2	5,000-7,000 /80%	1,250-1,750 /20%	6,250-8,750	7,000
18b	7,000	Up to 2	3,000-4,000 /80%	750-1,000 /20%	3,750-5,000	4,000
19	1,500	Up to 3	500 /80%	125 /20%	625	500

20	2,100	Up to 3	700 /80%	175 /20%	875	700
Total	**22,600**	**Up to 10**				

*The DOE share listed under the anticipated individual award size is the maximum amount of DOE funding that can be proposed for each AOI and/or sub-AOI. 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.
*** Applications are not being solicited at this time for AOIs with N/A in funding shares.

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 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.

ii. Estimated Project Period of Performance per Area of Interest

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

Area of Interest	Period of Performance
18a	24 Months (Single Phase/ Single Budget Period)
18b	24 Months (Single Phase/ Single Budget Period)
19	24 Months (Single Phase/ Single Budget Period)
20	24 Months (Single Phase/ Single Budget Period)

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 Sub-recipient.

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 Sub-recipient.

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 Sub-recipient.

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 Sub-recipient (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 Sub-recipient 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 Sub-recipient on another entity's application. An application that includes NETL as a Prime Recipient or Sub-recipient 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."

Value/Funding. DOE will NOT fund DOE/NNSA FFRDCs participating as a Sub-recipient 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 sub-award 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.

Cost Share. The Applicant should prepare the budgets using rates appropriate for funding the FFRDCs through sub-awards. The Applicant's cost share requirement will be based on the total cost of the project, including the Applicant's and the FFRDC/NL's portions of the effort.

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.

The FFRDC/NL's effort, in aggregate, shall not exceed **40% for AOI 18**, and **25% for all other AOIs,** of the total estimated cost of the project, including the DOE share, Applicant share and the FFRDC/NL's portions of the effort.

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 Sub-recipient 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 Sub-recipient 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. **Appendix X** 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 and 50% of the total allowable costs for demonstration and commercial application projects and must come from non-Federal sources unless otherwise allowed by law. 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. (See 2 CFR part 200.306 as amended by 2 CFR part 910.130 for the applicable cost sharing requirements.)

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 market 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.

To assist Applicants in calculating proper cost share amounts, DOE has included a cost share information sheet and sample cost share calculation in Appendix W to 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 sub-awards 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 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, Sub-recipients, 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 the funding was not provided to the state or local government by the Federal Government.

The Prime Recipient may not use the following sources to meet its cost share obligations 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 **Appendix W** 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 **Appendix W** 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 are deemed compliant if:

- The Full Application complies with the maximum DOE share of the individual award size in Section I.C of the FOA;
- The Full Application complies with the content and form requirements in Section IV.A and IV.B 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 are deemed responsive if:

- The application meets the technical requirements as described in the "Objectives/Areas of Interest" contained in Section I.C of the FOA; and
- The Applicant/application meets the Eligibility Criteria in Section III 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. **Applications which do not meet ALL of the form and content requirements listed below will be considered noncompliant (See Section III Compliance Criteria). DOE will NOT review or consider noncompliant applications.** 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 **single** 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 Compliance Criteria). DOE will not review or consider noncompliant submissions.

Applicants are responsible for meeting the 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.A 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 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 (**25** 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)	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
	Sub-award Budget Justification, if applicable – SEE DETAILED INSTRUCTIONS BELOW	Microsoft Excel	Sub-awardee_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 WP as the file name (e.g., lanlWP.pdf or lincolnWP.pdf).
	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
	Foreign Entity Participation waiver request, if applicable	PDF	FN_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	PDF	CBP.pdf
	Current and Pending Support	PDF	CPS.pdf
	Transparency of Foreign Connections	PDF	BusinessSensitive.pdf
	Potentially Duplicative Funding	PDF	PDFN.pdf
	Technology Maturation Plan (**AOI 18 ONLY**)	PDF	TMP.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 Sub-recipient(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 **25** 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) **single** 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 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 Compliance Criteria).

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

The project narrative (**25** 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 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.
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.A. 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 **Appendix Y** 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.
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 **25** pages. Full Applications which do not conform to ALL of the requirements listed above will be considered noncompliant (See Section III 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 if an award is made. 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) **single** 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) **single** spaced with font no smaller than 11 point. Applicants shall prepare the PMP in the format provided in **Appendix Z** 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 sub-awardees 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 2 pages when printed on 8.5" by 11" paper with 1 inch margins (top, bottom, left, and right) **single** 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 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 Sub-recipients and Contractors, and provide all requested documentation (e.g., a Federally approved rate agreement, vendor quotes). Applicants should include costs associated with 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. Sub-award Budget Justification (if applicable)

Applicants must provide a separate detailed budget justification for each Sub-recipient that is expected to perform work estimated to be more than $100,000 or 50 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 sub-award budget justification (if applicable) must be commensurate with that provided by the Prime Recipient. Save the information in a single file named "Sub-awardee_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 sub-awards 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. Sub-awards 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 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 Sub-recipient 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 Sub-recipient'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 Sub-recipients). 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. SF-LLL: Disclosure of Lobbying Activities (if applicable)

Recipients and Sub-recipients 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."

xviii. Waiver Requests: Foreign Entity Participation and Performance of Work in the United States

(a) Foreign Entity Participation:

As set forth in Section III, all Prime Recipients receiving funding under this FOA must qualify as domestic entities. To request a waiver of this requirement, the Applicant must submit an explicit waiver request in the Full Application. See **Appendix X** for a list of the necessary information that must be included in a request to waive this requirement. Save the waiver request(s) in a single PDF file titled "FN_Waiver" and click on "Add Optional Other Attachment" to attach.

(b) Performance of Work in 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 a written waiver request to DOE. See **Appendix X** for a list of the necessary information that must be included in a request to waive the Performance of Work in the United States requirement.

xix. 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 **Appendix AA** of this FOA. Save this plan in a single file named DMP.pdf' and click on "Add Optional Other Attachment" to attach."

xx. 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 Plan 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" **Appendix HH**, 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:

Applicants to all AOIs are required to submit a preliminary Environmental Justice Questionnaire as part of their Full Application. Submission of this questionnaire is required as part of the Community Benefits Plan (CBP) with the Full Application, and failure to submit the questionnaire may result in rejection of the application without further consideration. Applicants shall answer the questions provided in **Appendix FF** of this FOA.

3) Workforce Implications:

Applicants to all AOIs are required to submit a preliminary Economic Revitalization and Job creation Questionnaire. Submission of this questionnaire is required as part of the CBP with the Full Application, and failure to submit the questionnaire may result in rejection of the application without further consideration. Applicants shall answer the questions provided in **Appendix GG** of this FOA.

See the "R&D Community Benefits Plan Guidance" **Appendix HH**, 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.

xxi. Current and Pending Support (April 2023)

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 Sub-recipient 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)
- 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. §§ 3729-3703 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 format approved by the National Science Foundation (NSF), which 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://www.nsf.gov/bfa/dias/policy/nsfapprovedformats/cps.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. If the NSF format is 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.[3]

xxii. 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 of 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 sub-awards/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 Sub-recipients.

[3]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.

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.F. Intellectual Property Developed Under This Program of this FOA for more information on the DEC and DOE Patent Waiver.

xxiii. Transparency of Foreign Connections

Applicants must provide the following as it relates to the proposed Recipient and Sub-recipients. Include a separate disclosure for the Applicant and each proposed Sub-recipient. 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 mailing 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;

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 Sub-recipient has foreign ownership or control;
6. Percentage, if any, that the proposed Recipient or Sub-recipient is wholly or partially owned 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 Sub-recipient;
10. 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;
11. 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. 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 Sub-recipient is a publicly traded company, provide the above information for shareholders with an interest greater than 5%;
12. 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
13. 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 this plan in a single file named "BusinessSensitive.pdf" and click on "Add Optional Other Attachment" to attach.

xxiv. 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 under 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 this plan in a single file named "PDFN.pdf" and click on "Add Optional Other Attachment" to attach.

xxv. Technology Maturation Plan (if applicable)

FOR AOI 18 ONLY: Applicants are required to submit a Technology Maturation Plan as part of their Full Application. 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 TMP in the format provided in **Appendix DD** of this FOA. Save this plan in a single file named TMP.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.B Participants and Collaborating Organizations)
- Current and Pending Support (See Section VI.B 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

The Recipient agrees that at least **90 percent** of the direct labor cost for the project (including Sub-recipient labor) shall be incurred in the United States, unless the Recipient can demonstrate to the satisfaction of the Department of Energy that the United States economic interest will be better served through a greater percentage of the work being

performed outside of the United States. The Prime Recipient must flow down this requirement to its Sub-recipients.

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, Sub-recipients, 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

Foreign travel and associated costs are not allowable under this FOA.

L. Equipment and Supplies

To the greatest extent practicable, all equipment and supplies purchased with funds made available under this FOA should be American made. This requirement does not apply to used or leased equipment.

Property disposition will 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.

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.

Merit Review Criterion 1: Scientific and Technological Merit (40%)

- Thoroughness of the description of the proposed technology and degree to which the proposed technology or methodology meets the stated objectives of the FOA and the relevant AOI.
- 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.
- Feasibility of the proposed concept; the degree to which the proposed work is based on sound scientific and engineering principles.

Merit Review Criterion 2: Technical Approach and Understanding (30%)

- Adequacy and feasibility of the Applicant's approach to achieving the objectives of the AOI.
- Feasibility, appropriateness, rationale, and completeness of the proposed Statement of Project Objectives, such that there is a logical progression of work.
- The adequacy and completeness of the Project Management Plan (PMP) in establishing baselines (technical scope, budget, schedule) 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.

Merit Review Criterion 3: Technical and Management Capabilities (15%)

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

Merit Review Criterion 4: R&D Community Benefits Plan (15%)

- 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; and
  - 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.
- Adequacy and completeness of the preliminary responses provided to the Environmental Justice Questionnaire.
- Adequacy and completeness of the preliminary responses provided to the Economic Revitalization and Job Creation Questionnaire.
- Adequacy in which J40 principles and objectives are described in the Environmental Justice Questionnaire and the Economic Revitalization and Job Creation Questionnaire.

B. Other Selection Factors

i. Program Policy Factors

In addition to the Merit Review 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 and methods 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)[4].
- 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, and/or lesser environmental risks. Environmental risk includes, but is not limited to, an adverse impact to air, soil, water, or an increase in overall cradle to grave greenhouse gas footprint (carbon dioxide equivalent, CO2e).
- 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.
- 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.

[4] 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.

C. Other Review Requirements

i. Risk Assessment (May 2023)

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:

- Financial stability;
- Quality of management systems and ability to meet the management standards prescribed in 2 CFR 200 as amended by 2 CFR 910;
- History of performance;
- Audit reports and findings; and
- 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 180 and must require non-Federal entities to comply with these provisions. These provisions restrict Federal awards, sub-awards 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 threats to United States research, technology, and economic security from undue foreign government influence when evaluating risk. If high risks are identified and cannot be sufficiently mitigated, DOE may elect to not fund the Applicant.

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. 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.

ii. 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.

iii. 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 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 Sub-recipient 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 Sub-recipient 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 Sub-recipients 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 sub-awards.

v. Export Control (April 2023)

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 Sub-recipients 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 selected Applicant must immediately report to DOE any export control violations related to the projected funded under the DOE award, at the Prime or Sub-recipient level, and provide corrective action(s) to prevent future violations.

vi. 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 Sub-tasks 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;
- Coordinating related project activities with Sub-recipients 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 (FECM), in coordination with multiple DOE/FECM 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.

vii. 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.

viii. 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.

ix. 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.

x. 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.

xi. Interim Conflict of Interest Policy for Financial Assistance

The DOE interim Conflict of Interest Policy for Financial Assistance (COI Policy) can be found at PF 2022-17 FAL 2022-02 Department of Energy Interim Conflict of Interest Policy Requirements for Financial Assistance.

This policy is applicable to all non-Federal entities applying for, or that receive, DOE funding by means of a financial assistance award (e.g., a grant, cooperative agreement, or technology investment agreement) 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 Sub-recipient 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.**

xii. 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 Sub-recipient 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.

xiii. 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 VI.B.xiii.

xiv. Fraud, Waste and Abuse (April 2023)

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 grants and cooperative agreements should 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 (currently FAPIIS). 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 and Sub-recipients (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.

xv. Real Property and Equipment

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.

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. Sub-award 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 Sub-award Reporting System (FSRS) is the reporting tool Federal prime awardees (i.e., prime contractors and prime grants Recipients) use to capture and report sub-award and executive compensation data regarding their first-tier sub-awards to meet the FFATA reporting requirements. Prime awardees must register with the new FSRS database and report the required data on their first-tier sub-awardees/Sub-recipient 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:	Jodi Collins
E-mail:	jodi.collins@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 (April 2023)

Applicants should not include trade secrets 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.

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 the submission (e.g., Concept Paper, Full Application). 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 application, and other Applicant submissions must be marked as follows and identify the specific pages containing trade secrets or business sensitive, proprietary, or otherwise confidential information:

> **Notice of Restriction on Disclosure and Use of Data**:
> Pages [**list applicable pages**] of this document may contain trade secrets or business sensitive, 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 Business Sensitive, Trade Secrets, 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 and non-disclosure agreements prior to reviewing an application. Non-Federal personnel conducting administrative activities must sign a non-disclosure agreement.

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's Office of Fossil Energy and Carbon Management has issued a class patent waiver that applies to this FOA. Under this class waiver, any 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 an 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.B 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.

Rights in Technical Data: Normally, the government has unlimited rights in technical data created under a DOE agreement. Delivery or third-party licensing of proprietary software or data developed solely at private expense will not normally be required except as specifically negotiated in a particular agreement to satisfy DOE's own needs or to ensure the commercialization of technology developed under a DOE agreement.

G. Program Covered Under Special Protected Data Statute

This program is covered by a special protected data statute. The provisions of the statute provide for the protection from public disclosure, for a period of up to **five [5]** years from the date of the development of data that would be trade secret, or commercial or financial information that is privileged or confidential, if the information had been obtained from a non-Federal party. Generally, the provision entitled, Rights in Data--Programs Covered Under Special Protected Data Statutes (Item 4 under 2 CFR 910 Appendix A to Subpart D), would apply to an award made under this announcement. This provision will identify data or categories of data first produced in the performance of the award that will be made available to the public, notwithstanding the statutory authority to withhold data from public dissemination and will also identify data that will be recognized by the parties as protected data. Any entity receiving an award or sub-award under this announcement has the right to opt out of such data protection.

H. 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 Sub-recipient 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.

I. 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.

J. 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).

K. 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.

L. 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, sub-contracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

M. 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.

N. 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)

O. Annual Compliance Audits

If an institution of higher education, non-profit organization, or state/local government is a Prime Recipient or Sub-recipient 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 Sub-recipients (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.

P. 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.

Q. Indirect Rates

Potential Recipients and major Sub-recipients will need to demonstrate how indirect rates are developed using an acceptable government methodology or current rate agreement. The Prime Recipient and major Sub-recipients 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.

R. Prohibition on Certain Telecommunications and Video Surveillance Services or Equipment (April 2023)

As set forth in 2 CFR 200.216, Recipients and Sub-recipients 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; 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.

S. 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 continuing 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 physically relocate 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.

T. Implementation of Executive Order 13798, Promoting Free Speech and Religious Liberty

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

U. 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:

(1) Recipients, Sub-recipients, contractors, and sub-contractors 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 Sub-recipients, contractors, and sub-contractors.

(3) Recipients, Sub-recipients, contractors, and sub-contractors 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.

DOL's Office of Federal Contractor Compliance Programs (OFCCP) uses a neutral process to schedule compliance evaluations. Consult OFCCP's Technical Assistance Guide[5] to gain an understanding of the requirements and possible actions the Recipients, Sub-recipients, contractors, and sub-contractors must take. Additional guidance may also be found in the National Policy Assurances, produced by DOE.

V. Foreign Collaboration Considerations

a. Consideration of new collaborations with foreign entities and governments. The Recipient will be required to provide DOE with advanced written notification of any potential collaboration with foreign entities 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 or government regarding the potential collaboration or negotiating the terms of any potential agreement.

b. Existing collaborations with foreign entities 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

[5] 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.

monetary value. Things 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 – AREA OF INTEREST 1: CLEAN HYDROGEN COST REDUCTIONS VIA PROCESS INTENSIFICATION & MODULARIZATION FOR HYDROGEN SHOT

******AOI 1 was previously issued******

Research Sought

Hydrogen is a desirable energy carrier due to its high mass energy density and because it is a non-carbon fuel. In addition to its value as a fuel, hydrogen is an essential feedstock for numerous uses in refining, chemicals, carbon-free fuel (e.g., ammonia), and more.

The use of solid carbonaceous feedstocks (e.g., biomass, MSW, legacy coal waste, and waste plastics) in a gasification process integrated with pre-combustion carbon capture is one way to produce clean hydrogen. The gasification pathway to clean hydrogen provides a technology option that does not require the net input of electricity, offering advantageous pairing with electrolysis assets in a portfolio that must deliver uninterrupted energy supply. However, historical commercial experience of gasification-based hydrogen production is in large scale units, requiring large capital investment.

Modular gasification systems sized in range of 5–50-megawatt electric equivalent (MWe) offer an economical, lower risk, and more flexible alternative due to their lower capital investment requirements and ability to cater to local community needs and niche applications. However, modular systems are greatly disadvantaged by economies of scale limitations.

To address the cost disadvantage introduced by smaller scale, and to achieve overall cost reductions in hydrogen production in general, this AOI seeks innovations that leverage process intensification and modularization to streamline capital and operational cost drivers. Process intensification includes developing more efficient and compact systems through the optimization of critical parameters and/or combining multiple unit operations into a single subsystem that can accomplish multiple tasks simultaneously. The goal of process intensification concepts funded through this AOI is to increase specific throughput (i.e., an increase in output per given equipment size) to have benefits for both energy efficiency and capital cost efficiency, thus reducing the cost per unit hydrogen output of modular-scale systems. Cost reductions of this sort will make progress towards DOE Hydrogen Shot initiative's goal targeting hydrogen cost of $1 per one kilogram of clean hydrogen.

In addition to leveraging process intensification for cost reductions, this AOI also seeks applications for exclusively clean hydrogen. Therefore, biomass must be the feedstock for gasification R&D applications under this AOI. The Applicant may choose research approaches that include the blending of waste materials into the biomass; however, inclusion of waste blending into biomass feed is not mandatory.

Specific examples of technologies that might be addressed include, but are not limited to, the following: (1) selective hydrogen extraction from various gasification unit operations (e.g. the gasifier, or raw syngas quench, or WGS reactor) that might have combinatorial benefits on reducing equipment size, advantageously shifting reaction equilibrium, advantageously affecting gas phase space velocity via density change, etc.; or (2) CO_2 removal technologies integrated and combined with gasification system unit operations for capital cost efficiency; or (3) the combining of multiple unit operations (e.g. syngas cleanup systems, water gas shift (WGS)) into a single unit operation to achieve an overall reduction in the system's unit operation count. Holistic approaches with gas separation/pollutant removal technologies are central to these endeavors. In all cases, these should apply at modular scale (5–50 MWe equivalent) so that these small-scale gasification-based plants/systems would have reduced total capital investment costs to make these types of plants more attractive in the marketplace.

Successful Applicants must report project findings in a manner that enables techno-economic modeling and analysis, which could be executed by any interested party, including but not limited to project performers, DOE analysts, and third-party independent entities. Data reported by the project performer must be transparent enough to enable analysis by third parties or independent organizations.

Technical Elements that Must be Included in Applications

The Applicant needs to clearly explain how the proposed work could be reduced to practice in small modular scale such that it may be appropriately sized for sites containing finite quantities of biomass and waste materials (e.g., biomass waste, MSW, legacy coal wastes) as applicable. Noting that biomass and waste materials often have low heating value, the Applicants must demonstrate that their process is able to operate on feedstock(s) exhibiting lower heating content and possibly high variability in energy content. Applicants must fully identify and address gasification technology problems and how the challenge of high purity hydrogen production would be addressed in a proposed R&D project. Applicants must address the likely efficacy of their proposed technology to address various aspects of cost reductions (e.g., capital savings, efficiency boosts, etc.), thus providing narrative to demonstrate the technology's potential for significant progress towards the Hydrogen Shot hydrogen cost target. Applications must provide justification that the technical approach can offer significant advancement over existing commercial technology.

Research Scope and Attributes that are Not of Interest

R&D specifically not of interest includes:

- Systems based on air blown gasification.
- Any current commercially available technologies reduced to practice without performance enhancing innovations or technological advancement.
- R&D that cannot be reduced to practice within a modular gasification context at scales relevant for utilizing biomass feedstocks with minimal need for transport and related logistics, which is important to keep life-cycle carbon emissions low. This AOI defines such

"relevant scales" as 5 to 50 MWe.

- R&D directed towards the utilization of newly mined coal as feedstock.
- R&D that seeks utilization of coal wastes affiliated with on-going mining operations.
- R&D approaches that cannot assist in attaining the Administrations net-zero carbon emissions goals.

Applications that include aspects listed above, which have been identified as not being of interest, will be considered non-responsive and will not be evaluated.

Although the inclusion of certain waste materials into biomass feedstock is allowable under this AOI, Applicants who elect to do so will not receive a higher score for that decision under AOI-1 because the objectives of this AOI is for capital cost reductions via process innovations. R&D to enable waste feedstock use should apply under AOI-2 instead.

Anticipated Technology Readiness Level

Beginning of project: 2-3

End of project: 3-4

Modular gasification is not a new idea, but certain technologies required to achieve the cost reductions and performance optimizations desired for effective competition of gasification in the modern hydrogen production arena may be developmental, consistent with DOE Technology Readiness Level (TRL) 2. A previous FOA estimated the TRL of waste plastics gasifiers to be about 2–3. This, however, was justified by the fact that existing gasifiers were robust enough to handle the implementation of exotic fuels with minor adjustments and mainly required the development of newer supporting technologies to be successful. The level of process intensification espoused in this AOI requires a fundamental reimagining of the engineering of existing systems, including the gasifier. As such, a starting TRL of 2–3 is considered appropriate (with proofs-of-concept still needing to be defined and established and/or more work required to validate the basic mechanisms and performance).

At the end of any projects approved through this AOI, a TRL of 3–4 is expected (one-point TRL advancement). Specifically, TRL 4 indicates that process components or systems will have been validated at laboratory scale. This degree of TRL advancement implies a significant laboratory effort involving a study of at least one component of gasification systems that have been optimized for hydrogen production, be it a novel oxygen blown gasifier, WGS reactor, or acid gas removal system, etc.

Success Metric(s)

- DOE's program efforts in this space would be considered successful if DOE can analyze project results to illustrate/quantify the technology advancement's potential, and if that analysis shows significant improvement or advantage in the economic performance of the hydrogen

technology in terms of one or more of the following: (1) process or thermodynamic efficiency of gasification-based hydrogen, (2) significant reduction in relevant equipment sizes for a fixed fuel or syngas throughput and composition.

- Report of project findings by project performers in a manner that enables techno-economic modeling and analysis, which could be executed by project performers, DOE, or third-party independent entities. Data reported by the project performer must be transparent enough to enable analysis by third parties or independent organizations.
- Presentation of clear and concise results that demonstrate the advancement of the technology to at least TRL 3–4 by DOE standards. This shall include a single component proof-of-concept that allows for either the synthesis and/or combination of two or more important processes of the gasification, fuel preparation, or syngas cleanup sections of a theoretical gasification plant or the high-level optimization of at least one such system that can reasonably be expected to reduce the overall capital cost commensurate in capacity to an equivalent conventional technology.
- Project results significantly help reduce costs of gasification-based clean hydrogen production, to accord with DOE's Hydrogen Energy Earthshot initiative targeting a cost of $1 per one kilogram of clean hydrogen by the end of the current decade.[6]

Technology Maturation Plan (TMP)

A TMP is not required with the application but is required 90 days after award, with a final TMP due within 90 days of project completion. A template for the TMP is provided in **Appendix DD** of this FOA.

Environmental Justice Questionnaire

A preliminary "Environmental Justice Questionnaire" is required with applications and will be evaluated for this AOI. This preliminary version will later be updated for the final report. A completed "Environmental Justice Questionnaire" will be required as an attachment to the final report. The questionnaire is provided in **Appendix FF** of this FOA.

[6] https://www.energy.gov/eere/fuelcells/hydrogen-shot

APPENDIX B – AREA OF INTEREST 2A: CLEAN HYDROGEN FROM HIGH-VOLUME WASTE MATERIALS AND BIOMASS

******AOI 2A was previously issued******

Research Sought

In the nascent hydrogen economy, modular clean hydrogen production from locally available low-cost materials could provide an alternative to pipeline delivery or cryogenic tanker, by right-sized distributed production next to the consumer (e.g., a dedicated plant next to a hydrogen fueling station). Modular gasification of feedstocks such as legacy coal waste, biomass, and potentially other waste (e.g., plastic waste destined for a landfill) might fill this niche with a viable and market-competitive alternative to large-scale conventional natural gas-based hydrogen and help smooth out intermittent renewable energy-based hydrogen production. Localized production of clean hydrogen by modular gasification and using inexpensive feedstocks could enable production consistent with the urgency of DOE's Hydrogen Energy Earthshot initiative targeting cost of $1 per one kilogram of clean hydrogen by the end of the current decade.

However, conventional gasification process technology's large experience base for gasifiers and gasification systems unit operations is for coal or biomass feedstocks, not legacy coal waste, waste plastics, and other waste materials. Introducing a complex feedstock blend of biomass mixed with legacy coal wastes, mixed plastics, MSW and/or other wastes is likely to create issues with feed preparation/feeding to the gasifier vessel (sticking and fouled burners), new issues with syngas cleanup (given the slate of unusual contaminants that may be present in mixed wastes containing biomass and plastics), and corrosion issues particularly in high-temperature zones of gasification vessels and certain other unit operations. Given the significant differences and lack of experience with mixed wastes from varied and inconsistent sources, and with biomass that may also exhibit variability, R&D is needed to adapt or leverage known gasifier technology to a preponderance of mixed waste and biomass as the feedstock.

Proposals are sought for R&D to advance innovative and flexible modular (5–50 MWe equivalent) gasifier technology and gasification processes using a blended feedstock of biomass mixed with variable loadings of legacy waste coal, waste plastics, MSW and/or other wastes to produce greater than 99% hydrogen purity based on the final application. Proposals may seek to explore effects and seek enabling technology for gasification of mixed feeds, define extent of issues in these suspect areas/unit operations, and devise solutions.

Technical Elements that Must be Included in Applications

Successful proposals must clearly explain limitations in current state of the art technology that prevents commercial activity from confidently utilizing high-volume waste materials as gasifier feedstock. Applicants must also explain how the proposed work addresses the current limitations

and how the emerging technology, if successful, could be reduced to practice in small modular scale. Flexible and modular (5–50 MWe equivalent) oxygen blown gasifier technology is sought such that it may be appropriately sized for sites containing finite quantities of waste materials (e.g., biomass waste, MSW, legacy coal wastes).

Noting that waste materials often have low heating value, the Applicants must demonstrate that their process is able to operate on wastes with lower heating content and high variability in energy content. Applicants must fully identify and address gasification technology problems and how the challenge of high purity hydrogen production would be addressed in a proposed R&D project. Applicants must address the likely efficacy of their proposed technology to address various anticipated operational issues to demonstrate the technology's potential contribution to DOE's Hydrogen Shot initiative. Applications must provide justification that the technical approach can offer significant advancement over existing commercial technology.

Research Scope and Attributes that are Not of Interest

Applicants proposing pathways to clean hydrogen via process intensification and modularization concept development should respond to AOI-1 rather than AOI-2. For the purposes of this FOA, process intensification involves strategies to combine multiple operations and/or steps into fewer unit(s) or step(s) such that an overall efficiency improvement and/or cost reduction is realized.

Applications that propose commercially available technologies without innovations or technological advancement are not of interest.

Anticipated Technology Readiness Level

Beginning of project: 3

End of project: 4-5

Gasification of coal at large scale and biomass at small to medium scale have been accomplished commercially, implying high TRLs for those systems. However, gasification of mixed legacy coal waste, waste plastics and biomass is not practiced commercially; a previous FOA estimated the TRL of waste plastics gasifiers to be about 3–4. This was justified by the fact that existing gasifiers were robust enough to handle the implementation of exotic fuels with minor adjustments and mainly required the development of newer supporting technologies to be successful. Tackling mixed feeds of waste materials and biomass per the intent of this AOI requires a fundamental reengineering of many aspects or unit operations of gasification systems including the gasifier. As such, a starting TRL of 3 is considered appropriate (with proofs-of-concept still needing to be defined and established and/or more work required to validate the basic mechanisms and performance).

A TRL of 4–5 is expected by project end. Specifically, TRL 4 indicates that process components or systems will have been validated at laboratory scale. This degree of TRL advancement implies a significant laboratory effort that achieves optimization of at least one component of the gasification system for the mixed waste and biomass feedstock, be it a feeder, gasifier burner, or syngas cleanup step(s), etc.

Success Metric(s)

- DOE's program efforts in this space would be considered successful if DOE can analyze project results to illustrate/quantify a degree of improvement for gasification and gasification unit operations performance on mixed waste feedstocks for clean hydrogen production. A benefit of the modular gasification-based hydrogen production technology/supporting technology would typically be indicated in one or more of the following: (1) overcoming process issues of blended feedstocks of biomass mixed with wastes feeding to established gasifier types, (2) overcoming issues of gasifier performance on these blended feedstocks, (3) overcoming issues with syngas cleanup with these blended feedstocks, (4) overcoming corrosion issues resulting from these blended feedstocks, or (5) overcoming other relevant gasification systems issues resulting from these blended feedstocks.

- R&D project(s) awarded under this FOA should advance efforts by DOE in improving the cost (via efficiency improvements and leveraging low value waste feedstock) for clean hydrogen, as articulated by the broader Hydrogen Shot initiative. Clean hydrogen production from gasification of blended feedstocks of biomass mixed with wastes will boost the hydrogen economy while lessening environmental impact of landfills and other waste materials and even helping to eliminate legacy coal waste impoundments from decades of past production.

- Project results will help reduce costs of gasification-based clean hydrogen production, to accord with DOE's Hydrogen Energy Earthshot initiative targeting a cost of $1 per one kilogram of clean hydrogen by the end of the current decade.

Performers may need to prepare process models, perform analyses, or at least make basic calculations to estimate performance and costs. Quality guidelines/recommendations for performing analyses, and useful specifications (such as composition of typical feedstocks in gasification-based hydrogen production processes) are offered in FOA **Appendix V**.

Technology Maturation Plan

A Technology Maturation Plan (TMP) is not required with the application but is required 90 days after award, with a final TMP due within 90 days of project completion. A template for the TMP is provided in **Appendix DD** of this FOA.

Environmental Justice Questionnaire

A preliminary "Environmental Justice Questionnaire" is required with applications and will be evaluated for this AOI. This preliminary version will later be updated for the final report. A completed "Environmental Justice Questionnaire" will be required as an attachment to the final report. The questionnaire is provided in **Appendix FF** of this FOA.

APPENDIX C – AREA OF INTEREST 2B: SENSORS & CONTROLS FOR CO-GASIFICATION OF WASTE PLASTICS IN PRODUCTION OF HYDROGEN WITH CARBON CAPTURE

******AOI 2B was previously issued******

Research Sought

Low density, durability, corrosion resistance, and low cost have made plastics a widely used material in the modern world. However, their widespread use has led to them composing a sizeable portion of household waste. In 2018, plastics composed about 12.2% of municipal solid waste in the United States[7]. About 8.7% of waste plastics were recycled, 15.8% combusted with energy recovery, and 75.5% landfilled (about 27 million tons). Plastics vary in difficulty for recycling, depending upon their composition and their condition when collected. Thermoplastics such as LDPE and HDPE are more easily recycled, requiring sorting and melting, but others are more difficult or impossible. Combustion of these non-recyclable plastics can reduce the volume of waste requiring disposal and provide a source of energy[8]. Through gasification, waste plastics may be used more valuably as a chemical feedstock, and a source of hydrogen[8].

While gasification technologies for plastics are able to build upon the technologies developed for coal, they do have some different challenges[9]. Gasification provides greater flexibility in mixing variable plastics and plastics with other feedstocks, such as legacy coal waste and biomass, when compared to pyrolysis[9]. Addition of plastics to gasification of legacy coal waste increases the production of hydrogen. However, difficulties with plastics include their low thermal conductivity and sticky behavior, when compared to legacy coal wastes and biomass. These properties make the materials handling aspects of different gasification technologies of increased importance for commercial implementation. Entrained flow, fluidized beds, spouted beds, and novel oxygen blown gasifier approaches are potentially viable approaches for waste plastic co-gasification.

Pollutant emissions from combustion or gasification of plastics is a significant concern. Uncontrolled combustion of plastic waste produces a number of regulated pollutants, including volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), dioxins, furans,

[7] United States Environmental Protection Agency, *Advancing Sustainable Materials Management: 2018 Fact Sheet.* Dec. 2020.

[8] Umberto Arena, "Process and technological aspects of municipal solid waste gasification. A review," *Waste Management*, Volume 32, Issue 4, 2012, Pages 625-639, https://doi.org/10.1016/j.wasman.2011.09.025

polychlorinated biphenyls, and halogens[9, 10, 11]. Gasification is an attractive alternative to direct incineration of waste plastic since it reduces the formation of dioxins and aromatic compounds. A well-engineered and operated gasification process should produce a high calorific value syngas (often with high hydrogen content), completely consume char resulting in easily recoverable ash or slag and should not require any additional installations for air/water pollution abatement beyond typically deployed acid gas and particulate control systems within the plant. Proper control of the gasification process is able to keep the emissions of these pollutants below regulatory limits.

This funding opportunity seeks to advance sensor technology to optimize processes for co-gasification of biomass and mixed wastes, including waste plastics. Advanced sensor technologies would enable commercial practice of gasifying waste materials in an environmentally responsible manner to provide for clean hydrogen in a net-zero carbon economy. Such a high-performing system would require real-time information on the feedstock stream into the gasifier and conditions within the gasification process, including early detection of environments that favor the formation of undesirable pollutants and their associated precursors.

If the Applicant chooses to include coal wastes in its blend of biomass and mixed wastes, then those coal wastes must be taken from legacy stockpiles that are not associated with ongoing operations that are producing additional coal wastes.

Technical Elements that Must be Included in Applications

The Applicant must clearly explain how the technology is relevant to control of the co-gasification process and how it is a significant advance over existing commercial technology.

Research Scope and Attributes that are Not of Interest

The following aspects are not of interest to this AOI. Applications that include these aspects will be considered non-responsive and will not be evaluated.

- Sensors whose recommended use/design is for co-gasification systems that feature newly mined coal or newly generated coal wastes,
- Sensors and/or controls systems for oxidizing environments or combustion systems, and
- Sensor systems validated in boiler applications, or in open pit / open burn (OPOB) applications

[9] Rinku Verma, K.S. Vinoda, M. Papireddy, A.N.S. Gowda, "Toxic Pollutants from Plastic Waste- A Review," *Procedia Environmental Sciences*, Volume 35, 2016, Pages 701-708, https://doi.org/10.1016/j.proenv.2016.07.069

[10] Athanasios Valavanidis, Nikiforos Iliopoulos, George Gotsis, Konstantinos Fiotakis, "Persistent free radicals, heavy metals and PAHs generated in particulate soot emissions and residue ash from controlled combustion of common types of plastic," Journal of Hazardous Materials, Volume 156, Issues 1–3, 2008, Pages 277-284, https://doi.org/10.1016/j.jhazmat.2007.12.019

[11] Paul M Lemieux, Christopher C Lutes, Dawn A Santoianni, "Emissions of organic air toxics from open burning: a comprehensive review," *Progress in Energy and Combustion Science*, Volume 30, Issue 1, 2004, Pages 1-32, https://doi.org/10.1016/j.pecs.2003.08.001

Anticipated Technology Readiness Level

Beginning of project: 3 - 4

End of project: 4-5

Technologies of interest are expected to start at TRL 3 or 4, and mature to TRL 4 or 5 by the end of the project resulting in a TRL increment of at least 1 by the end of the project (see **Appendix CC**). For the kinds of sensors and controls research being solicited in this AOI, TRL 3 starting points infer that laboratory-scale studies have already been accomplished to physically validate the analytical predictions of separate elements of the technology. To attain TRL 4, experience must be acquired on the component and/or sensor for system validation in a laboratory environment, meaning that simulated syngas can be obtained by mixing bottle gases and controlling pressure and temperature to conditions of interest. To attain TRL 5, the sensor system must be validated in a relevant environment, meaning syngas is generated from a feedstock material by a bench scale, or pilot scale device.

Success Metric(s)

Technologies of interest are expected to start at TRL 3 or 4, and mature to TRL 4 or 5 by the end of the project.

Technology Maturation Plan

A TMP is not required with the application but is required 90 days after award, with a final TMP due within 90 days of project completion. A template for the TMP is provided in **Appendix DD** of this FOA.

Environmental Justice Questionnaire

A preliminary "Environmental Justice Questionnaire" is required with applications and will be evaluated for this AOI. This preliminary version will later be updated for the final report. A completed "Environmental Justice Questionnaire" will be required as an attachment to the final report. The questionnaire is provided in **Appendix FF** of this FOA.

APPENDIX D – AREA OF INTEREST 3: NOVEL HIGH-PURITY HYDROGEN SEPARATIONS

***** Area of Interest 3 is Not Funded at this time *****

Research Sought

The global and domestic demand for high-purity hydrogen is expected to increase over the coming years as consumers transition from traditional carbonaceous fuels toward lower-carbon or zero-carbon energy carriers. Current hydrogen production at an industrial scale is dominated by SMR, which currently accounts for approximately 75% of global hydrogen production while consuming about 6% of global natural gas produced. As of 2019, coal-derived hydrogen production constituted 23% of global hydrogen, produced from 2% of the world's coal production.[12] However, alternatives to traditional fossil fuel feedstocks are needed for clean hydrogen production. Alternative feedstocks include biomass and carbonaceous waste materials such as MSW, waste plastic, and legacy coal wastes. Utilizing waste materials for hydrogen provides a means for recycling carbon, and biomass provides a means to achieve net-zero or net-negative carbon-based energy carriers. However, gasification technology needs to be enabled by two additional technologies to provide clean hydrogen: (1) pre-combustion carbon capture and (2) hydrogen separation technology.

Advancements in supporting process technologies are needed to enable clean hydrogen techniques to capture more of the global hydrogen production market share. Conventional, large-scale, solvent-based methods of hydrogen separation are energy-intensive and costly. Advancements in hydrogen separation technology may enable higher degrees of market penetration for gasification-based clean hydrogen production from feedstocks like biomass, MSW, and waste plastic.[13]

Proposals are sought for development of high-performance hydrogen separation technologies capable of producing relatively pure (greater than 99%) hydrogen from syngas derived from gasification of biomass, legacy coal wastes, waste plastics, and other wastes that are burdensome to communities. These innovative technologies must have performance and/or cost advantages relative to commercially available technology, and may include, but are not limited to, membranes, sorbents, and other innovative gas separation techniques. The use of artificial intelligence and machine learning (AI/ML), computational modeling, and advanced manufacturing for accelerating technology development may provide viable R&D pathways for clean hydrogen separations.

[12] International Energy Agency. (June 2019). "The Future of Hydrogen," Report prepared by the International Energy Agency for the G20, Japan.
[13] Arena et al. (2015). "A life cycle assessment of environmental performances of two combustion and gasification-based waste-to energy technologies," *Waste Manag*. **41**, 60–74.

Technical Elements that Must be Included in Applications

The Applicant must clearly explain how the technology is suited to novel/innovative hydrogen separations in the context of gasification of alternative feedstocks for clean hydrogen production, and how it is a significant advance over existing commercial technology.

Research Scope and Attributes that are Not of Interest

R&D specifically not of interest includes:

- Any current commercially available technologies for hydrogen separations reduced to practice without performance enhancing innovations or technological advancement.
- R&D that cannot be reduced to practice within scales relevant for hydrogen separations in the context of utilizing alternative feedstocks (including biomass feedstocks) with minimal need for transport and related logistics, which is important to keep life cycle carbon emissions low. This AOI defines such "relevant scales" as 5 to 50 MWe.
- R&D approaches that cannot assist in attaining the administrations net-zero carbon emissions goals.

Applications that include aspects listed above, which have been identified as not being of interest, will be considered non-responsive and will not be evaluated.

Anticipated Technology Readiness Level

Beginning of project: 2-5

Some leading (economically favorable) hydrogen separation methods, such as industrial and academic membranes, are generally at an early stage of Technology Readiness Level (TRL) 3, but with directed funding and development could move to the pilot-plant scale and beyond.

Novel sorbents are also being developed at the laboratory scale and represent a low level of technology readiness. Any additional novel hydrogen separation innovation will have a low TRL, and this is to be expected.

End of project: 3-6

Project success will be ensured by advancing the TRL from the initial starting level. It is expected that a project with an initial TRL of 2 should be able to advance to a TRL of 3 or higher during the duration of this project. Advancement toward commercialization is highly desired.

Success Metric(s)

- It is DOE's intention that any proposed work under the FOA will enable meaningful technology advancement toward commercialization. This may be quantitatively defined as

an advancement in TRL of at least one point, irrespective of starting TRL.

- DOE's program efforts in this space would be considered successful if the DOE can analyze project results to quantify the technology advancement, and if that analysis concludes that a substantial performance and/or cost benefit is likely. Benefit of the novel high-purity hydrogen separation technology would typically be indicated in terms of improvement(s) in one or more of the following: 1) overall reduced capital and operating cost of the high-purity hydrogen separation system, 2) ability to accelerate the downstream use of hydrogen via rapid and efficient hydrogen separation.
- Report of project findings by project performers in a manner that enables techno-economic modeling and analysis. Data reported by the project performer must be transparent enough to enable typical/appropriate scope of techno-economic modeling and analysis consistent with technology maturation level.
- Overall responsiveness to need for R&D for enhancement of environmental standards and increasing availability, efficiency, and reliability of gasification systems, with the broad goals to foster U.S. economic security through maintaining fuel diversity and energy resiliency while helping to address the essential carbon reductions required to halve GHG emissions by 2030 and attain a carbon pollution-free electricity sector by 2035, leading to a zero-carbon U.S. economy by 2050. Also, showing potential for investment in coal, oil/gas, and power plant communities via clean energy that strengthens the economy and creates jobs, and fostering environmental justice to address adverse human health, environmental, and climate-related impacts.

Technology Maturation Plan

Requirements for AOI 3 will be defined through future amendments to this FOA document.

Workforce Readiness Plan

Workforce readiness plan is not required.

Environmental Justice Questionnaire

A completed "Environmental Justice Questionnaire" will be required for this AOI as an attachment to the final report.

A preliminary "Environmental Justice Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.)

APPENDIX E – AREA OF INTEREST 4: ADVANCED AIR SEPARATION FOR LOW-COST H_2 PRODUCTION VIA MODULAR GASIFICATION

******AOI 4 was previously issued******

Research Sought

Clean/decarbonized hydrogen production from gasification of biomass and wastes is strongly enabled by the use of oxygen in gasification reactions. Oxygen input to the gasifier is essentially a prerequisite for high-quality syngas production and efficient pre-combustion carbon capture. Although state of the art cryogenic air separation is efficient and cost-effective at large scales, at modular/distributed scales it becomes non-competitive or infeasible. Resorting to other sources (e.g., delivery of expensive tanker truck loads of liquid oxygen, use of conventional membrane-based oxygen separation units) tends to be too expensive or fails to yield oxygen of sufficient purity.

The focus of this AOI is the advancement of modular air separation that will be needed to support modular gasification-based hydrogen production. Small modular energy systems can realize a cost benefit from oxygen production that is less expensive than comparable cryogenic-based air separation at these scales.

Proposals are sought for development of oxygen production or air separation technologies capable of supplying oxygen to modular gasifiers (5–50 MWe equivalent) that are using mixtures of biomass and wastes as feedstock, from which hydrogen of greater than 99% purity would be the desired end-product, with either a lower cost and/or higher efficiency than state of the art air separation or oxygen production methods. Technical approaches and advancements in certain technical areas for modular air separation will likely be of interest in this context, including but not limited to the following:

- Advanced membranes
- Novel sorbents
- Chemical looping
- Process integration approaches involving oxygen production.

Technical Elements that Must be Included in Applications

The Applicant must clearly explain how the technology is suited to novel/innovative oxygen production to support gasification of alternative feedstocks for clean hydrogen production, and how it is a significant advance over existing commercial technology.

The application should include process analysis showing technical feasibility of the air separation/oxygen production method in the context of a gasification-based system for clean/decarbonized hydrogen production. In other words, the gasification process must have

net-zero carbon performance, with the air separation/oxygen production system underpinning this performance requirement.

Research Scope and Attributes that are Not of Interest

Applications specifically not of interest would include any current commercially available oxygen separation technology, and approaches that do not build upon or extend the state of the art in continued advancement in efficiency and cost reductions of oxygen separations that can be leveraged to the modular hydrogen production problem.

Anticipated Technology Readiness Level

Oxygen production technologies for large-scale gasifiers are well established commercially, implying high TRLs for those systems. However, dedicated oxygen production to support modular gasification is not practiced commercially; starting TRLs for certain membrane and sorbent-based technologies at the desired throughputs, and which can be applied to the gasification-based hydrogen production problem, are expected to be in the range of TRL 2–4.

At the end of any projects approved through this AOI, a TRL of 3–5 is expected. Specifically, TRL 5 indicates that process components/systems will have been validated at laboratory scale with relatively high fidelity, in fact almost approaching prototype scale and fidelity. This degree of TRL advancement implies a significant laboratory effort involving a study of at least one novel innovation in oxygen production technology that can be applied to modular gasification-based hydrogen production.

Success Metric(s)

- DOE's program efforts in this space would be considered successful if DOE can analyze project results to illustrate/quantify the technology advancement's potential, and if that analysis concludes that a substantial performance and/or cost benefit is likely. Benefit would typically be indicated in terms of improvement(s) in one or more of the following: (1) more affordable oxygen production/air separation technologies at smaller and modular scales than comparable cryogenic-based air separation, (2) more efficient oxygen production/air separation technologies at smaller and modular scales than comparable cryogenic-based air separation, or (3) reduction of facility footprint.
- Report of project findings by project performers in a manner that enables techno-economic modeling and analysis. Data reported by the project performer must be transparent enough to enable typical/appropriate scope of techno-economic modeling and analysis consistent with technology maturation level.
- Overall responsiveness to need for R&D for enhancement of environmental standards and increasing availability, efficiency, and reliability of gasification systems, with the broad goals to foster U.S. economic security through maintaining fuel diversity and energy resiliency while helping to address the essential carbon reductions required to halve GHG emissions by 2030 and attain a carbon pollution-free electricity sector by 2035, leading to

a zero-carbon U.S. economy by 2050. Also, showing potential for investment in coal, oil/gas, and power plant communities via clean energy that strengthens the economy and creates jobs, and fostering environmental justice to address adverse human health, environmental, and climate-related impacts.

Technology Maturation Plan

A TMP is not required with the application but is required 90 days after award, with a final TMP due within 90 days of project completion.

Workforce Readiness Plan

Workforce readiness plan is not required.

Questionnaires

(1) A completed "Environmental Justice Questionnaire" will be required for this AOI as an attachment to the final report. (See **Appendix FF** for the Questionnaire)

(2) A preliminary "Environmental Justice Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.)

(3) A completed "Economic Revitalization and Job Creation Questionnaire" will be required for this AOI as an attachment to the final report. (See **Appendix GG** for the Questionnaire)

(4) A preliminary "Economic Revitalization and Job Creation Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.)

APPENDIX F – AREA OF INTEREST 5: SOLID OXIDE ELECTROLYSIS CELL (SOEC) TECHNOLOGY DEVELOPMENT FOR HYDROGEN PRODUCTION

******AOI 5 was previously issued******

Research Sought

High-temperature SOEC systems offer a potentially attractive option for producing hydrogen because of high efficiency and system flexibility. SOEC technology is based on reversing the operation of an SOFC. Instead of using hydrocarbon fuels (reformed into hydrogen and carbon monoxide) and air to electrochemically produce power, an SOEC system is supplied with power and steam to produce hydrogen. SOECs can be divided into two categories based on the type of electrolyte: oxygen ion-conducting SOECs (O-SOECs) and proton-conducting SOECs (P-SOECs). SOECs typically operate between 600–800°C in both pressurized and non-pressurized system configurations.

SOEC systems are essentially developed around existing SOFC technologies so there is the potential for good synergy between research in both areas. Due to commonalities like high-temperature operation, stack interconnect and seal material issues, impurity-related degradation mechanisms, and relatively high system cost, many of the technical challenges in SOFC design carry over to SOEC systems. However, SOECs have shown much higher degradation rates than their SOFC counterparts. Significant R&D is needed to bring the SOEC technology to widespread commercial-level adoption.

Applications are being sought for bench-scale R&D to improve fundamental understanding of degradation mechanisms in SOEC materials and development of new or modified materials that are applicable to O-SOEC and P-SOECs, both with operating temperatures above 600 °C. R&D can focus on any element of the cell, stack, or system component. Successful projects will accomplish the validation of concepts at a laboratory scale. Applicants will be requested to coordinate with EERE's H2NEW consortium, established by HFTO to avoid duplication, leverage synergies, and maximize effectiveness.[14]

R&D areas of interest include, but are not limited to:

- Development of cells and stacks that can operate in SOEC mode with low degradation, (target: less than 0.5%/1,000 hours) high round trip stack efficiency (target greater than 70%) and higher current densities
- Understanding the effect of operational parameters on cell and stack performance (reversible cyclic frequency between power and electrolyzer mode, current density and cell voltage, thermal cycling)

[14] https://www.energy.gov/eere/articles/doe-launches-two-consortia-advance-fuel-cell-truck-and-electrolyzer-rd

- Cost reduction via improvements in materials and manufacturing
- Oxygen ion conducting and proton conducting electrolytes
- Oxygen electrodes—address delamination and chromium poisoning
- Fuel electrodes—contamination and redox stability
- Reversible SOFC–SOEC operation—optimized SOFC operation under both natural gas and 100% hydrogen
- Pressurized operation in order to reduce the need for hydrogen compression for transportation and storage
- Surface and microstructure modification for lower area-specific resistance, lower degradation, and lower cost (e.g., atomic layer deposition, infiltration, etc.).

This AOI is focused on cell and small-stack (up to six cells) level R&D. (System level demonstrations will not be funded under this AOI.)

Research Scope and Attributes that are Not of Interest

System-level demonstrations will not be funded under this AOI.

Anticipated Technology Readiness Level

Beginning of project: TRL 3

End of project: TRL 4

It is anticipated that projects under this AOI will begin at TRL 3, where in the technology concept and/or application are formulated, active R&D is initiated, and initial performance attributes have been established. Projects under this AOI should end at TRL 4. This is the first step in determining whether the individual components will work together as a system. Proposed projects must demonstrate that the basic technology components have been integrated and validated in a laboratory environment. 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.

Success Metric(s)

Successful projects will result in validation of concepts in a laboratory environment. These will typically include individual cell or stack components that are successfully tested at a laboratory-scale and are ready to be evaluated in a multi-cell stack.

APPENDIX G – AREA OF INTEREST 6: SOFC AND SOEC COMPONENT MATERIALS THERMODYNAMIC DATABASE

***** Area of Interest 6 is Not Funded at this time *****

Research Sought

Intermediate- and high-temperature solid state electrochemical systems operate as a solid oxide fuel cell (SOFC) to produce power from hydrocarbon and renewable fuels. These systems can also operate as solid oxide electrolysis cells (SOEC) to electrolyze water for hydrogen production. High temperature operation in both fuel cell and electrolysis mode improves overall process efficiency, enables faster reaction kinetics and smaller polarization losses, and allows the use of non-noble metals for the construction of cells and stacks. However, there remains a need to improve electrical performance and lower performance degradation over long-term operation.

High temperature operation of electrochemical systems in both fuel cell and electrolysis modes is complex due to multi-step chemical and electrochemical processes involving surface (solid-gas), interface (solid-solid) and bulk (solid and gas) reactions under high steam partial pressure. These lead to formation of undesirable reaction products and localized phases, changes in bulk chemistry, and poisoning of the electrodes. Improvement in electrical performance and performance stability require a thorough understanding of bulk materials chemical stability, thermochemical reaction processes at surface, near surface and interfaces along with thermodynamic (long-term) stability of complex oxides, reaction products and thermochemistry of corrosion processes of metals and alloys in oxidizing and reducing gases. Knowledge of thermochemical processes based on thermodynamics and energetics of reactant materials and reaction products are not only considered essential for developing mechanistic understanding of electrical performance degradation, but also helpful in identification of novel component materials that offer improved performance through chemical and structural stability.

While complex perovskites and fluorites have been effectively used for ion and electron exchange at electrodes and oxygen ion/proton conduction through electrolyte, metals and alloys have been largely used for the fabrication of cell interconnect and balance of plant components. Exposure of the above components to high temperatures and complex gas atmospheres (from oxidizing to reducing with local changes in oxygen, hydrogen, carbon activity, and presence of intrinsic and extrinsic impurities) promote changes in the defect chemistry and formation of reaction products, influencing ohmic and polarization losses. There is a need to understand thermodynamic properties involving defect chemistry, interface compound formation facilitated by segregation, interdiffusion, gas-phase adsorption, and chemical interactions at given activities of constituents.

Recent advances in experimental techniques and computational tools, to predict and measure thermodynamic properties, offer pathways to develop thermodynamic reaction models to

experimentally validate necessary conditions for reaction processes (solid-solid and solid-gas). Appropriate boundary conditions (exposure and operating conditions) can be developed and optimized for long-term electrical performance and performance stability of fuel cells and electrolyzers.

Applications are being sought for the measurements of thermodynamic properties of SOFC and SOEC component materials that can be used in a predictive capability to design stable electrochemical systems, while maintaining high performance. The data should be experimentally based and verifiable at device operating conditions. The objective of this AOI is to expand the thermodynamic database related to SOFCs and SOECs in both pressurized and non-pressurized systems. The thermodynamic database must serve both oxide ion and proton conductors with cell operating temperature above 600°C. A comprehensive compilation and evaluation of thermodynamic data for various systems and reactions over a wide range of compositions and conditions is of interest.

Requirements for AOI 6 will be defined through future amendments to this FOA document.

Anticipated Technology Readiness Level

Beginning of project: 3. The technology concept and/or application is formulated. Detailed analysis to support the assumptions has been initiated. Initial performance attributes have been established.

End of Project: Not applicable

Success Metric(s)

Successful projects will result in demonstration of thermodynamic stability of materials under investigation followed by cell fabrication and testing in a laboratory environment.

APPENDIX H – AREA OF INTEREST 7: INITIAL ENGINEERING DESIGN OF ADVANCED CO_2 CAPTURE FROM HYDROGEN PRODUCTION

******AOI 7 was previously issued******

Research Sought

In 2017, the International Energy Agency Greenhouse Gas R&D Program released a report titled the "Techno-Economic Evaluation of Hydrogen Production with CO_2 Capture". This report focuses on baseline performance and costs of incorporating CO_2 capture technologies to an SMR hydrogen plant. Around 90% of the feedstock used in the production of hydrogen are from fossil fuel with SMR being the leading technology for H_2 production from natural gas or light hydrocarbon streams. Most modern SMR-based hydrogen production facilities have achieved efficiencies that reduce CO_2 emissions down to nearly 10% above its theoretical minimum. Further reduction of CO_2 emissions from hydrogen production could only be achieved by the integration of Carbon Capture, Utilization and Storage (CCUS). However, the report identified challenges in the application of CCUS to SMR plants. These include substantial increases in levelized cost of hydrogen at high carbon capture rates, increased natural gas consumption, and/or reduced amounts of electricity and/or steam exported to the grid.[15]

DOE-FE's program in Carbon Capture has been developing carbon capture technologies since 2001 with the goal of decreasing the cost of carbon capture systems. Technologies developed to date have focused on the capture of CO_2 directly from fossil fuel power plant flue gas. The Carbon Capture program is aiming to leverage this past research in materials and systems development for application to the conditions and process requirements of SMR or autothermal reforming (ATR) plants to reduce the impact on levelized cost of hydrogen while decreasing the carbon intensity.

The objective of this AOI is to complete the initial design of a commercial-scale, advanced CCUS system that separates, stores, and utilizes more than 100,000 tonne/year net CO_2 with 90%+ carbon capture efficiency, from a steam reforming or autothermal reforming plant to produce hydrogen with 99.97% purity, from natural gas. Applications with lower annual emissions will be considered non-responsive and will not be reviewed.

There are two sub-topic areas for this AOI:

7a: Advanced CCUS systems from Steam Methane Reforming Plants, and
7b: Advanced CCUS systems from Autothermal Methane Reforming Plants

[15] 2017-02.pdf (ieaghg.org)

Applicants shall propose to complete an initial design of an advanced CCUS system capable of operation in an industrial setting. CCUS systems proposed to this AOI (Sub-topic 7a or Sub-topic 7b) should have already attained a TRL of 6 based on previous developments for hydrogen production and coal-based and/or natural gas-based power generation. The Applicant should select and propose a specific H_2 plant representative of a current or planned new facility.

The Applicant should identify and propose plausible options for CO_2 storage or utilization. However, the initial design study should **not** include work to design the geological/enhanced oil recovery storage systems. If CO_2 is stored, its quality and quantity should meet the requirements of the proposed storage solution. If alternative CO_2 utilization pathways are considered, all associated process steps should be included in the design, and techno-economic analysis (TEA).

Engineering design shall cover both the CCUS system and balance-of-plant. 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 power the CCUS system. The latter may include integration of an external energy source (natural gas-, coal-fueled) or integration of the CCUS into the existing plant. If the CCUS system requires co-generation of power or steam for its operation, it must include CO_2 capture, compression, storage, and utilization from both the hydrogen generation and co-generation plant(s).

For both Sub-topic **7a** and Sub-topic **7b**, Applicants shall propose to complete the following during their project:

- *Initial engineering design*. Design of the advanced CCUS system shall result in preparation of a capital cost estimate including the cost of capture in **$/tonne CO_2 net captured** from the hydrogen plant, and the **levelized cost of hydrogen**. The engineering design shall include, at a minimum, process flow diagrams, utility flow diagrams, piping and instrument diagrams, heat and material balances, plot plan, layout drawings, engineered process and utility equipment lists, vendor quotations, resourcing and work force plans.

- *Techno-economic analysis (TEA)*. At the conclusion or their projects, the Applicants are required to revise and submit the final TEA.

- *Environmental Health and Safety (EH&S) Analysis*. Applicants are required to submit an EH&S analysis of the proposed technologies (e.g., carbon capture and storage [CCS], CO_2 storage, and utilization) at the completion of their project.
- 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.

For both Sub-topic **7a** and Sub-topic **7b**, Applicants are expected to submit the following with their applications.

- *CCUS Technology Description and Technology Readiness Level Evaluation.* The Applicants

must describe the proposed, advanced CCUS technology including, but not limited to, process diagrams, and hardware sketches. It is expected that the Applicants have already demonstrated their CCUS technology **at TRL 6.** The Applicants should provide data to support the readiness for commercial deployment of the proposed CCUS technology based on Applicant's previous test results. The Applicants are expected to complete a State Point Data Table for their technology.

- *Host site selection.* The Applicant should select and propose a specific SMR (Sub-topic **7a**) or ATR (Sub-topic **7b**) industrial plant producing hydrogen from natural gas located **exclusively in the United States.**

- *Hydrogen Plant Description and CCUS Integration.* The Applicant must describe the existing SMR (Sub-topic **7a**) or ATR (Sub-topic **7b**) plant, including, but not limited to, process diagrams, hardware sketches and emissions profiles (e.g., location, concentration and temperature of the CO_2-containing flue gas, contaminants). The description should also include details regarding how the CCUS system will be integrated into the hydrogen plant. If multiple emission sources exist at the hydrogen plant, the Applicant should describe whether aggregation of the sources into one stream, upstream of the CCUS facility, is proposed.

- *CO_2 storage/utilization pathways.* Applications should identify plausible options for CO_2 storage or utilization. If CO_2 is stored, its quality and quantity should meet the requirements and the capacity of the proposed storage solution.

- *H_2 storage/utilization pathways.* Applications should identify plausible options for hydrogen utilization and/or storage. However, the initial design study should NOT include work to design the hydrogen utilization or storage systems.

- *Summary of the Preliminary Techno-economic analysis.* Applicants will be required to submit the summary results of the preliminary TEA covering both the CCUS system and balance-of-plant, and to report the levelized cost of hydrogen with and without the CCUS system. Applicants are required to revise the TEA at the conclusion of their project.

Applicants shall provide a complete description of the proposed project addressing all Merit Review Criteria.

Research Scope and Attributes that are Not of Interest

Applications with lower annual emissions (than 100,000 tonne/year net CO_2) will be considered non-responsive and will not be reviewed.

Areas considered to be outside the scope of this AOI, and so considered non-responsive include, but are not limited to:

- R&D on post-combustion CO_2 capture technologies (other than engineering analysis) at the

laboratory/bench scale, engineering, or pilot scale,

- R&D on pre-combustion CO_2 capture technologies (other than engineering analysis) at the laboratory/bench scale, engineering, or pilot scale,
- Oxy-combustion and chemical looping configurations at the laboratory/bench scale, engineering, or pilot scale,
- R&D on CO_2 use and conversion technologies (other than engineering analysis),
- R&D on oxy-combustion and chemical looping configurations,
- R&D on CO_2 compressor development (other than engineering analysis),
- R&D on technologies for biological capture of CO_2,
- R&D on CO_2 capture technologies from air,
- The use of the following heat/energy sources to decarbonize the hydrogen plant will be considered non-responsive, and cannot be used for energy for the CCUS system:
    - Any fuel switching from original industrial fuel sources to hydrogen or any type of biomass
    - Electrification to provide heat to the hydrogen plant
    - Integration with other sources such as nuclear or renewables (solar, wind, geothermal, hydro, etc.) to provide heat in any manner to the hydrogen plant.

Anticipated Technology Readiness Level

Beginning of project: TRL 6

End of project: TRL 6

Projects awarded under this AOI will develop an initial design for a commercial-scale carbon capture system processing CO_2 containing flue or other stack gases, generated during H_2 production in a steam methane reforming (Sub-topic **7a**) or autothermal reforming facility (Sub-topic **7b**) supplying high-purity hydrogen. CCUS technologies proposed should have already attained a TRL level of 6.

Success Metric(s)

By 2023, projects will develop an initial engineering study for a commercial-scale, CCUS system that separates and stores more than 100,000 tonne/year net CO_2 with 95% purity from an industrial plant producing hydrogen from natural gas. The CCUS capture system must achieve a net carbon capture efficiency of 90+% with minimum impact on the levelized cost of hydrogen. The commercial industrial plant should produce hydrogen of 99.97% purity. These designs should provide the basis for the subsequent deployment of CCUS projects that are targeting the 45Q tax credits.

APPENDIX I – AREA OF INTEREST 8: FRONT-END ENGINEERING DESIGN STUDIES FOR CARBON CAPTURE SYSTEMS AT DOMESTIC INDUSTRIAL FACILITIES PRODUCING H_2 FROM NATURAL GAS

******AOI 8 was previously issued******

Research Sought

In 2017, the International Energy Agency Greenhouse Gas R&D Programme released a report titled the "Techno-Economic Evaluation of Hydrogen Production with CO_2 Capture". This report focuses on baseline performance and costs of incorporating CO_2 capture technologies into a steam methane reforming (SMR) hydrogen plant. Around 90% of the feedstock used in the production of hydrogen are from fossil fuels with steam methane reforming (SMR) being the most commonly used technology for H_2 production from natural gas or light hydrocarbon streams. Most modern SMR based hydrogen production facilities have achieved efficiencies that could reduce CO_2 emissions down to nearly 10% above its theoretical minimum. Further reduction of CO_2 emissions from hydrogen production could only be achieved by the integration of CCUS. However, the report identified challenges in the application of CCUS to SMR plants. These include substantial increases in levelized cost of hydrogen at high carbon capture rates, increased natural gas consumption and/or reduced amounts of electricity and/or steam exported to the grid.

Many point source carbon capture technologies developed by the U.S. Department of Energy's Office of Fossil Energy and Carbon Management (DOE-FECM) over the last 20 years for power sector applications can be applied to mitigate CO_2 emissions from such SMR and autothermal reforming (ATR) industrial facilities producing hydrogen from natural gas. The Point Source Carbon Capture program is aiming to leverage this past research in materials and systems development for application to the conditions and process requirements of SMR and ATR plants to reduce the impact on levelized cost of hydrogen while decreasing the carbon intensity.

DOE recently announced the selection of projects that will focus on the initial engineering design studies for carbon capture and storage systems at industrial facilities producing H_2 from natural gas.[16] To further understand system costs, performance, and business case options, this AOI aims to solicit applications for Front-End Engineering Design (FEED) studies for carbon capture systems at domestic industrial facilities producing H_2 from natural gas. This enhanced understanding will allow DOE-FECM to accelerate deployment of low carbon hydrogen generation technologies from natural gas and help the U.S. achieve greenhouse gas reduction targets noted in Executive Order 14008: an emissions-free power sector by 2035, and a net-zero carbon economy by 2050.

[16] U.S. Department of Energy Selects 12 Projects to Improve Fossil-Based Hydrogen Production, Transport, Storage and Utilization | Department of Energy

Under AOI-8, there are two sub-topics:

Sub-topic 8a: Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Steam Methane Reforming (SMR) Facilities Producing H_2 from Natural Gas.

and,

Sub-topic 8b: Front-End Engineering Design Studies for Carbon Capture Systems at Domestic Autothermal Reforming (ATR) Facilities Producing H_2 from Natural Gas.

For **Sub-topic 8a** and **Sub-topic 8b**, the Applicants will propose to execute and complete a front-end engineering design study of a commercial-scale, advanced carbon capture system that separates 95% of the total CO_2 emissions with 95% CO_2 purity from an existing, domestic SMR (Sub-topic 8a) or ATR (Sub-topic 8b) facility. Advanced carbon capture systems proposed should have already attained a TRL of 6 or above based on previous developments for an industrial application or power generation. The advanced carbon capture system should separate more than 100,000 tonne/year net CO_2-equivalent (CO_2e) based on LCA. The Applicants must demonstrate how deployment of the proposed carbon capture system will promote creation of clean energy or manufacturing jobs located in hydrogen plant and associated manufacturing communities that are economically distressed and/or have been disproportionately harmed by the adverse environmental impacts of operating these plants.

The Applicants should select and propose a specific, domestic SMR (Sub-topic 8a) or a specific domestic ATR (Sub-topic 8b) facility that produces hydrogen with 99.97% purity, from natural gas. For Sub-topic 8a, the proposed host site should be an existing SMR facility or a SMR facility under construction that is expected to start commercial operation by the end of 2023. For Sub-topic 8b, the proposed host site should be an existing ATR facility, or a new ATR facility that is expected to start construction by the end of 2023.

The Applicants should identify and propose plausible options for CO_2 transportation, long duration carbon storage (i.e., geological storage or subsurface 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 and storage solution. However, the FEED study should **NOT** include work to design the systems for CO_2 transportation, long duration carbon storage, or CO_2 utilization.

Applicants to Sub-topic 8a and Sub-topic 8b, are required to propose teams that include the following:

- Hydrogen plant operator/owner,
- Carbon Capture technology developer or licensor, and
- Engineering, Procurement, and Construction (EPC) engineering firm(s).

If an Applicant is proposing the 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.

As successful technology commercialization and deployment requires a ready workforce, Recipients of an award under this AOI will be required to complete a Workforce Readiness Plan as part of the project. A suggested format for this Plan is contained in **Appendix EE** of this FOA. The Plan must include: (i) a description of the skillset and availability of the workforce; (ii) a description of the training required to prepare the workforce such as apprenticeships, certificates, certifications, or academic training; and (iii) if needed, a plan to collaborate with training providers or other stakeholders to develop necessary training that would not be otherwise available.

Under Sub-topic 8a and Sub-topic 8b, selected FEED projects will perform activities including, but not limited to, those listed below:

1. **Project Scope and Design** that includes research / business objectives and the summary of the proposed project.

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.

3. **Engineering Design Package**. Design of the carbon capture system shall result in equipment sizing fully substantiated with kinetic, heat, and mass transfer data, as well as justification for the choice of materials of construction. The cost estimate shall include the preparation of a capital cost estimate including the cost of capture in $/tonne CO_2 net captured from the hydrogen plant and the levelized cost of hydrogen (LCOH). The FEED shall include, at a minimum, process flow diagrams; carbon capture process model scaled-up for the proposed industrial facility; utility flow diagrams; piping and instrumentation diagrams; heat and material balances; plot plan; final layout drawings; complete engineered process and utility equipment lists; 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 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.

   Engineering design shall cover both the carbon capture system and balance-of-plant. 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 power the carbon capture system. 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 with the hydrogen plant. If the carbon capture 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 carbon capture system requires co-generation of power or steam for its operation, it must include CO_2 capture, compression, and storage from both hydrogen facility and co-generation plant.

The engineering design package should also cover the integration of the carbon capture process within the hydrogen plant, including but not limited to novel approaches to recover waste heat from the hydrogen plant and integrate it with the carbon capture system and design of pollution control upstream of the carbon capture system.

Successful Applicants will be required to submit: (i) an initial engineering design package 180 days after the project start 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) final engineering design package 90 days prior to project completion.

4. **Project cost estimate**. Design of the capture system shall support a capital cost estimate consistent with AACE (Association of the Advancement of Cost Engineering)[17] Class 3 with an expected accuracy range of -10% to -20% on the low side and +10% to +30% on the high side. Successful Applicants will be required to submit the project cost estimate 90 days prior to project completion.

5. **Business case analysis.** Successful Applicants will be required to prepare the business case analysis and submit it 90 days prior to project completion. If the plan includes the utilization of 45Q tax credits and/or Low Carbon Fuel Standard (LCFS) credits, the business case analysis shall include, at a minimum, details on the anticipated revenue and duration of the credits.

6. **Life Cycle Analysis (LCA).** Successful Applicants will be required to complete a final LCA and submit it 90 days prior to project completion.

7. **Environmental Health and Safety (EH&S) Analysis**. Successful Applicants will be required to submit an EH&S analysis of the proposed technologies 90 days prior to project completion. EH&S analysis should include discussion regarding air and water emissions, water utilization, solid waste streams, and potential environmental impacts of the

[17] AACE International Recommended Practice No. 18R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement and Construction for the Process Industries, Copyright 2005.

technology including toxicological effects and hazards of emissions and waste streams.

8. **Technology Maturation Plan (TMP).** Successful Applicants will be required to prepare a TMP in the format provided in **Appendix DD** of the FOA that shows how the technology will both increase in scale and decrease in cost through 2035. The TMP should also identify and propose plausible pathways on how the SMR facility 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, electrification, or other carbon dioxide removal (CDR) technologies (e.g., Direct Air Capture (DAC), biomass with carbon capture (BECCS)). However, the FEED study should **not** include work to design these technology options. The TMP should also include a sensitivity analysis and cost of hydrogen as a function of technology options proposed to achieve overall net zero carbon emissions. Also included in the TMP should be any data gaps that need to be addressed through R&D. 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.

9. **Environmental Justice Questionnaire.** Applicants are required to prepare and submit a preliminary Environmental Justice Questionnaire in the format provided in **Appendix FF** of the FOA. It is expected that award Recipients will, as needed, update this information throughout the course of the award and provide a more comprehensive summary of environmental justice considerations as an attachment to the final report.

10. **Economic Revitalization and Job Creation Questionnaire**

11. **.** The Applicants are required to submit a preliminary economic revitalization and job creation questionnaire associated with the proposed carbon capture. It is expected that award Recipients will, as needed, update this information throughout the course of the award and provide a more comprehensive analysis of economic revitalization and job creation outcomes as an attachment to the final report.

12. **Workforce Readiness Plan.** Successful Applicants will be required to prepare a Workforce Readiness Plan in the format provided in **Appendix EE** of the FOA and submit it as defined in the SOPO.

Technical Elements that Must be Included in Applications

For Sub-topic 8a and Sub-topic 8b, Applicants are expected to include the following *in the narrative section* of their applications:

- **Carbon Capture Technology Description and Technology Readiness Level Evaluation.** The Applicants must describe the proposed carbon capture technology including, but not limited to, process diagrams, and hardware sketches. It is expected that the Applicants have already demonstrated their carbon capture technology **at TRL 6 or above.** 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. **Applicants are required to provide complete information in the State Point Data Table to support the readiness of their technology.**

- **Host site selection**. For Sub-topic **8A**, Applicants must select and propose an existing SMR plant or an SMR plant under construction that is expected to start commercial operation by the end of 2023. For Sub-topic **8B**, Applicants must select and propose an existing ATR plant or a new ATR plant that is expected to start construction by the end of 2023. The host site must be located **exclusively in the United States.** The Applicant must provide documented evidence (i.e., host site commitment letter) that this site has agreed to participate in the FEED study. 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.

- **Hydrogen Plant Description and Carbon Capture Process Integration**. Applicants must describe the existing industrial plant, including, but not limited to, process flow diagrams and emissions profiles (e.g., location, concentration, temperature, pressure, and contaminants) of the CO_2-containing flue gas. The description should also include details regarding how the carbon capture system will be integrated into the SMR/ATR facility, including, but not limited to, the proposed criteria pollutants (e.g., NO_x, SO_x, particulate matter) abatement systems to be installed upstream of the carbon capture plant. If multiple emission sources exist at the hydrogen plant facility, the Applicant should describe whether aggregation of the sources into one stream, upstream of the carbon capture facility, is proposed.

- **Carbon Storage/Conversion options**. Applicants should identify and propose plausible options for CO_2 transportation, long duration carbon storage (i.e., geological storage or subsurface 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 matured their CO_2 conversion technology to TRL 6 or above. CO_2 pressure, quality, and quantity at the carbon capture plant "gate" should meet the requirements of the intended transport and storage 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[18] or other regional carbon capture and storage hubs under development. The Applicants should discuss how the timeline of the carbon

[18] https://netl.doe.gov/coal/carbon-storage/storage-infrastructure/carbonsafe

capture project will be linked to the development of the proposed CO_2 transportation, storage, and/or conversion option. However, the FEED study should NOT include work to design the systems for CO_2 transportation, long duration carbon storage, or CO_2 utilization.

- **H_2 storage/utilization pathways.** Applicants should identify plausible options for hydrogen utilization and/or storage. However, the FEED study should NOT include work to design the hydrogen utilization or storage systems.

- **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 or initial feasibility study (preferred) covering both the carbon capture system and balance-of-plant, (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 covering the advanced carbon capture system and balance-of-plant, (iii) the cost of the proposed advanced carbon capture system, (iv) LCOH, as well as (v) the cost of carbon capture. CO_2 pressure, CO_2 quality, and quantity at the carbon capture plant "gate" should meet the requirements of the intended transport, storage, or carbon utilization solution. The preliminary TEA and preliminary BCA included in the application should be prepared based upon prior engineering design and costing work. Preliminary LCA should be prepared, and preference will be given to Applicants that minimize life cycle GHGs.

The following item is required to be submitted as an attachment to the application and is not included in the Project Narrative page limitation.

- **Preliminary Economic Revitalization and Job Creation Questionnaire.** The Applicants are required to submit a preliminary economic revitalization and job creation questionnaire associated with the proposed carbon capture system. It is expected that award Recipients will, as needed, update this information throughout the course of the award and provide a more comprehensive analysis of economic revitalization and job creation outcomes as an attachment to the final report.

Research Scope and Attributes that are Not of Interest

Areas considered to be outside the scope of interest of this FOA are listed below. Applications that propose work in these areas will be considered non-responsive and will not be evaluated.

- R&D to advance the maturation of post-combustion and pre-combustion carbon capture technologies, apart from the required design of a carbon capture system;
- R&D to advance the maturation of CO_2 conversion technologies;
- R&D on CO_2 storage technologies;
- R&D on advanced power cycles (e.g., supercritical CO_2 cycle, oxy-combustion, and chemical looping configurations);

- R&D on CO_2 compression technologies, apart from 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 bioenergy with carbon capture (BECCS) technologies, enhanced weathering).

Anticipated Technology Readiness Level

Beginning of project: 6 or above

End of project: 6 or above

Success Metric(s)

By 2024, projects will develop a FEED study for a commercial-scale, advanced carbon capture system that separates 95% of the total CO_2 emissions with 95% CO_2 purity from a domestic SMR (Sub-topic 8a) or ATR (Sub-topic 8b) facility. The commercial industrial plant should produce hydrogen of 99.97% purity. The advanced carbon capture system should separate a minimum of 100,000 tonne/yr. net CO_2e based on LCA, with minimum impact on the levelized cost of hydrogen, suitable for long duration carbon storage or CO_2 conversion/utilization 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 and/or LCFS tax credits and will be early adopters of the technology.

Technology Maturation Plan

Applicants to Sub-topic 8a and Sub-topic 8b will be required to submit a preliminary TMP 90 days after award, with a final TMP due 90 days prior to project completion.

Workforce Readiness Plan

A Workforce Readiness Plan is required as a deliverable in the SOPO for this AOI. A template for this plan is located in **Appendix EE** of this FOA.

Environmental Justice Questionnaire

A preliminary "Environmental Justice Questionnaire" is required with applications and will be evaluated for this AOI. This preliminary version will later be updated for the final report. A completed "Environmental Justice Questionnaire" will be required as an attachment to the final report. The questionnaire is provided in **Appendix FF** of this FOA.

Economic Revitalization and Job Creation Questionnaire

A preliminary "Economic Revitalization and Job Creation Questionnaire" is required with applications and will be evaluated for this AOI. This preliminary version will later be updated for the final report. A completed "Economic Revitalization and Job Creation Questionnaire" will be required as an attachment to the final report.

APPENDIX J – AREA OF INTEREST 9: HYDROGEN COMBUSTION SYSTEMS FOR GAS TURBINES

******AOI 9 was previously issued******

Research Sought

This AOI seeks to develop a hydrogen-fueled combustion module for F-class, aeroderivative class, or industrial class gas turbines through engineering-scale prototype testing. An objective of this work will be to develop and test a retrofittable combustion module that could be deployed in a pre-commercial prototype combustion system and tested in a gas turbine. For this development, the fuels include high-purity hydrogen and a range of hydrogen and natural gas mixtures. Applications must specify the turbine class and associated combustor module for this R&D (each application can only identify one turbine class).

This AOI has three overarching goals:

1. Develop and test a retrofittable combustion module that can be replicated in a specified power generation gas turbine as a hydrogen-fueled combustion system.
2. Strive to maintain gas turbine performance while using hydrogen fuels.
3. Support a future full-scale pre-commercial gas turbine test on hydrogen fuels (government-funded work associated with this goal will not be funded through this AOI).

These goals should be addressed in the Technology Maturation Plan (TMP) requested for this AOI.

Applications must specify the class of turbine (F-class, aeroderivative class, or industrial class) for which the retrofittable combustion module will be developed. Applications under this AOI must identify the Sub-topic selection in the title of the application.

Turbine class Sub-topics include:

(**9a**) F-Class
(**9b**) Aeroderivative Class
(**9c**) Industrial Class

Applications will be evaluated within the selected class and not evaluated with applications submitted for other classes.

Technical Elements that Must be Included in Applications

Applications must include a TMP that shows current TRLs, progressing to commercial deployment. Guidelines for preparing the TMP are provided in **Appendix DD**.

Applications must include a preliminary test plan for engineering-scale testing of an appropriately sized combustion module (e.g., combustion can, burner, nozzle, test article, or test article matrix). Test plans should focus on the development, testing, control, performance, and commercial deployment of the combustion module. Successful applications will have opportunities to further develop the project test plan.

Applications must specify and justify the hydrogen fuel types proposed for testing. These fuels should include two general types: (1) a high hydrogen content fuel, approaching 100% hydrogen (e.g., hydrogen produced from electrolysis or SMR with CCS) and (2) mixtures of hydrogen and natural gas (percent-by-volume mixtures). Selected blends of natural gas and hydrogen should extend the current state-of-the-art for the selected gas turbine. The fuel specification and selection must be supported by the TMP. If appropriate for testing, anticipated trace fuel contaminants can be considered inert.

Applications must present a description of the engineering-scale test facility that will be used for the combustion module R&D. The description shall include a physical description of the facility as well as a description of the temperature, pressure, and flow rate measurement capabilities for the major constituents (fuel, air, exhaust, diluents, purge, test article, etc.). The description should also include the test article (combustion module) and instrumentation and control system.

Applications must address the performance of the combustion module and how performance will be improved through the proposed R&D. Performance parameters should consider, but are not limited to, emissions of NO_X, fuel turn-down, flame pattern and/or combustor-turbine interface, pressure and flame dynamics, diluents, control strategies, and fuel blend performance range. Performance should be assessed for the range of test articles (combustion models) evaluated and selected fuels. Likely diluents should be specified and impact on performance assessed. Applications must specify NO_X targets for the class of turbine selected and likely local emission limits for an expected commercial deployment.

Anticipated Technology Readiness Level

Beginning of project: 4

End of project: 6

For this AOI, technology is expected to start at a TRL of 4 and conclude work at a TRL of 6. For TMP development the pre-commercial prototype testing is expected to conclude at TRL 7.

Success Metric(s)

An engineering-scale combustion module is tested and meets specified performance parameters and demonstrates a TRL of 6 and is ready to be replicated and tested as a full-scale combustion system for pre-commercial prototype testing at a TRL of 7 or higher.

APPENDIX K – AREA OF INTEREST 10: PRE-COMMERCIAL TESTING OF A HYDROGEN FUELED GAS TURBINE

***** Area of Interest 10 is Not Funded at this time *****

Research Sought

This AOI seeks to test a hydrogen-fueled combustion system in an F-class, aeroderivative class, or industrial class gas turbine as a pre-commercial demonstration test. In terms of technology maturation, AOI 10 is a continuation of AOI 9—to advance gas turbine hydrogen combustion system technology from TRL 6–7 (This AOI is not restricted and participating in awards from AOI 9 is not a requirement to apply to this AOI). The objective of this AOI is to conduct a prototype precommercial demonstration test of a hydrogen-fueled gas turbine.

Requirements for AOI 10 will be defined through future FOA amendments.

Anticipated Technology Readiness Level

Beginning of project: Unspecified

End of project: 7-8

This AOI will advance hydrogen fueled combustion systems for gas turbines to a TRL of 7–8 through pre-commercial demonstration testing.

Success Metric(s)

Pre-commercial prototype demonstration test of a full-scale hydrogen fueled combustion system in a gas turbine to demonstrate a TRL of 7 over a range of advanced performance conditions.

APPENDIX L – AREA OF INTEREST 11: AMMONIA COMBUSTION SYSTEMS FOR GAS TURBINES

*******AOI 11 was previously issued*******

Research Sought

This AOI seeks to develop a technical understanding of applied ammonia combustion phenomena under gas turbine conditions. The goal of this AOI is to progress the technical understanding of ammonia combustion to enable the development of combustors that are capable of efficient, high-temperature, stable, low-NO_X operation while utilizing ammonia-based fuels.

Ammonia possesses advantages as a carbon-free fuel when compared to hydrogen due to its simplified storage requirements. However, ammonia is a challenging fuel for gas turbine applications due to its low flammability, low flame speed, and fuel-bound nitrogen content. The low flame speed could necessitate larger combustors to ensure complete fuel burn, and the high nitrogen content promotes the formation of fuel NO_X. These issues are significant since larger combustors could lead to difficulties in retrofit scenarios, and the increase in NO_X formation could result in NO_X emissions that are difficult to reduce to acceptable levels even with modern selective catalytic reduction systems.

Several strategies for ammonia combustion have been explored since it began gaining interest as a carbon-free fuel/hydrogen carrier.[19, 20] Combustion of pre-vaporized ammonia is possible, but the relatively slow chemical reaction rate between ammonia and air requires reduced air flow to increase residence time. This lowers the turbulence and reduces mixing, causing decreased combustion efficiency.[21] Fuel enhancement via hydrogen addition is one possible approach for improving the combustion performance of ammonia; however, partial dissociation or reforming of high-purity ammonia to produce a mixture of ammonia and hydrogen has been found to be an effective method for improving combustion performance of the fuel while avoiding the need for onsite storage/supply of hydrogen.[22]

Applications are being sought for applied laboratory- or bench-scale research and testing to improve the performance of ammonia combustion systems and develop design tools that will aid in scale-up. The fuel of interest for this AOI is high-purity ammonia, including, but not limited to, high-purity ammonia produced from the industrial Haber-Bosch process. However, Applicants may propose to utilize a range of fuel mixtures that could result from partial reforming of high-

[19] Bull, M.G. (1968). "Development of Ammonia Burning Gas Turbine," *Solar*. San Diego, USA. Final Technical Report.
[20] Kobayashi, H. et al. (2019). "Science and technology of ammonia combustion," *Proceedings of the Combustion Institute 37*(1), 109-133.
[21] Pratt, D.T. (1967). "Performance of ammonia fired gas turbine combustors," *Solar*. San Diego, USA. Report T-9-TS-67-5.
[22] Valera-Medina, A. et al. (2018). "Ammonia for power," *Progress in Energy and Combustion Science 69*, 63-102.

purity ammonia prior to combustion. Reforming strategies of interest include both catalytic and thermal approaches. Note that these reforming strategies should not completely reform all ammonia in the fuel mixture; rather, they should be used to reform the high-purity ammonia fuel only to the degree that is necessary for stable, efficient, and low-NO_X combustion. Applications must specify and justify the ammonia-based fuel(s) proposed for testing.

Applications should present a strong technical understanding of existing information related to combustion of ammonia in gas turbine applications in order to focus work and build upon the existing knowledge base. Testing conditions and geometries as part of this research can consider existing, new, and/or retrofit designs and should be relevant to gas turbines capable of land-based power generation [e.g., heavy-frame (e.g., H-class and F-class), aeroderivative, mid-size industrial gas turbines].

Applicants should address all three R&D subjects of interest, detailed below, and separate tasks into logical steps that will support the incremental development of ammonia combustors for land-based gas turbine power generation.

The first R&D subject of interest is the assessment and mapping of ammonia fuel combustion phenomena over a range of relevant gas turbine conditions and physical features, with the goal that the applied understanding would enable the preliminary design of a high-temperature and stable ammonia-fueled gas turbine combustor with low NO_X emissions. Accordingly, applications should consider the following:

- The fuel of interest is high-purity ammonia; however, partially reformed or synthetic mixtures that are representative of partially reformed ammonia may be utilized if the benefits have been justified within the application.

- The ammonia-containing fuels combustion assessment should consider test conditions and physical features (injectors, injector interactions, burners, swirlers, bluff bodies, vanes, etc.) representative of existing combustor designs, new combustor designs, and/or retrofit applications. Unique and novel approaches for purpose-built features made possible through advanced manufacturing to realize the goal of this AOI are encouraged.

- Several ammonia-fueled gas turbine flame phenomena of interest include blow off, flame extinction limit, flammability limits, combustion instability, flash back, flame holding, flame speed, hot spots, etc., particularly as a function of hydrogen content in the ammonia/hydrogen fuel.

- Assessment of ammonia-air premixing and ammonia fuel staging under relevant conditions and geometries, for the purposes of ensuring complete combustion and reducing NO_X formation to minimize ammonia and NO_x emissions.

- Application of advanced combustion diagnostics to obtain temporally and spatially resolved temperature and species measurements under relevant ammonia combustion

environments for computational model validation.

- Where pertinent, assess conditions relevant to turn-down range, dynamics, and load following transients.

The second R&D subject of interest is the development and validation of computational models for ammonia combustion. These models should be developed in parallel with the assessment and mapping of ammonia fuel combustion phenomena described above and should be validated against both literature and data gathered during the proposed research. The need for the development of these tools should be justified, and their development should build upon and leverage current state-of-the-art capabilities.

The third and final R&D subject of interest is the design, fabrication, and testing of a scaled-up combustor capable of efficient, high-temperature, stable, low NO_X operation while utilizing ammonia-based fuels. The scaled-up combustor should be appropriately scaled for the specific gas turbine of interest, which the Applicant must select. If the turbine of interest would require a combustor that is cost prohibitive, then an intermediate scale combustor may be considered; however, the Applicant must explain how deviations in the operating conditions of the intermediate scale combustor would impact the design of the full-scale combustor.

The design of the scaled-up or intermediate-scale combustor should be completed by utilizing the computational modeling tools developed during the proposed research. The Applicant should consider the design parameters of the scaled-up combustor and evaluate their potential implications for retrofit scenarios. A performance analysis of the scaled-up combustor design should also be completed to estimate its operability range and its performance in terms of efficiency and NO_X generation. Oxides of nitrogen in the 20 parts-per-million (ppm) range is the combustor exhaust target so that NO_X concentrations in the low single digit ppm range could be achieved at the power plant exhaust (deviations from this target value are acceptable—for example, in simple-cycle applications and where regional emissions targets may vary; deviations from this target should be justified in the application).

Fuel composition selection, combustor/turbine selection, and the decision of pursuing an existing, new, and/or retrofit application should be justified within the application from both a technical and economic perspective. These choices should also be reflected within the TMP.

Anticipated Technology Readiness Level

Beginning of project: 1-2

End of project: 3-4

For this AOI, technology is expected to start at a TRL of 1–2 and conclude work at a TRL of 3–4.

Success Metric(s)

Successful projects under this AOI will develop a technical understanding of applied ammonia fuel combustion phenomena under gas turbine conditions; develop computational tools to assist with the design and optimization of future combustors capable of utilizing ammonia fuels; and design, fabricate, and test a combustor design capable of stable, high-temperature, and low-NO_X operation while utilizing ammonia fuel in new and/or retrofit applications.

APPENDIX M– AREA OF INTEREST 12: DEMONSTRATION OF A ROTATING DETONATION ENGINE IN A GAS TURBINE

*******AOI 12 was previously issued*******

Research Sought

This AOI seeks to advance technical understanding of the application of a rotating detonation engine (RDE) in a hybrid-gas turbine cycle for the purpose of land-based power generation. An objective of this AOI is to demonstrate the integration of an axial compressor and turbine with an RDE while operating on hydrogen in air or blends of hydrogen and natural gas in air. Special attention should be given to maintaining turbine and compressor efficiency while maximizing the overall cycle efficiency. The primary focus of this AOI is on physical experimentation to demonstrate the technical objectives. Proposed computational studies should complement physical experimentation but must not be the sole focus of the study.

For near-term land-based power generation applications, pressure gain combustion devices will be required to efficiently integrate with both upstream and downstream turbomachinery. Computational studies such as Liu et al.[23] and Asli et al.[24] have provided insight to the challenges of transitioning a high Mach number unsteady flow from an RDE to a turbine. Additionally, Depperschmidt et al.[25] provided time-resolved flow field measurements of RDE exit flow with and without a diffuser aimed at attenuating the unsteady flow. A study at the Air Force Research Laboratory that was jointly funded by NETL[26] demonstrated the operation of an RDE on H_2 in air while coupled to the turbine of a T63 engine. While this study suggested much of the unsteady nature of the flow could be damped, the integration was not optimized for an RDE-turbine system. Further successful demonstration of an RDE-turbine integrated system is necessary to identify potential knowledge gaps.

[23] Liu, Z. et al. (2018). "Three dimensional optimization for subsonic axial turbines operating at high unsteady inlet Mach number," Proceedings of the 2018 AIAA Joint Propulsion Conf., July 9-11, 2018, Cincinnati, OH. DOI: https://doi.org/10.2514/6.2018-4480

[24] Asli, M. et al. (2020). "Aerodynamic Investigation of Guide Vane Configurations Downstream a Rotating Detonation Combustor," *ASME. J. Eng. Gas Turbines Power*, Nov 21, 2020, DOI: https://doi.org/10.1115/1.4049188

[25] Depperschmidt, D. et al. (2019). "Time-Resolved PIV Measurements of Flow Field at the Exit of a Diffuser Mounted on a Rotating Detonation Combustor," 2019 AIAA Propulsion and Energy 2019 Forum, Aug 19-22, 2019, Indianapolis, IN. DOI: https://doi.org/10.2514/6.2019-4379

[26] Naples, A. et al. (2017). "Rotating Detonation Engine Implementation into an Open-Loop T63 Gas Turbine Engine," AIAA SciTech Forum - 55th AIAA Aerospace Sciences Meeting, Jan 9-13, 2017, Grapevine, TX. DOI: https://doi.org/10.2514/6.2017-1747

This AOI has six targeted objectives:

1. Modify an existing gas turbine engine to accommodate replacement of the conventional combustor with a RDE operating on hydrogen in air or a blend of hydrogen and natural gas in air.

2. Develop and test an integrated architecture that maintains compressor and turbine efficiencies while minimizing the addition of downstream cooling and dilution and maximizes overall cycle efficiency. Experimentally or computationally characterize how this architecture would scale to a heavy frame (F-class or larger) or aeroderivative gas turbine engine.

3. Quantify the performance (through physical experimentation) of the hybrid gas turbine system, including cycle efficiency and NO_X emissions, while varying conditions to emulate changes in cycle operating loads, compression ratio, and combustor inlet temperature.

4. Demonstrate a viable strategy for minimizing cooling for the RDE and downstream turbomachinery while maintaining cycle efficiency over full- and part-load conditions. For example, consider operating at fuel lean conditions to reduce the need for combustor and turbomachinery cooling.

5. Quantify the impact of compressor-RDE-turbine integration on thermo-mechanical fatigue associated with the unsteady behavior of the RDE through a combined computational-experimental effort.

6. Demonstrate, and accurately quantify through physical experimentation, the potential for pressure gain through the development of a low-pressure loss RDE inlet that at a minimum produces no pressure loss from the compressor to the turbine.

Applications should present a strong technical understanding of existing knowledge related to the design, operation, and performance diagnostics associated with rotating detonation combustion and gas turbine engines for the purpose of land-based power generation. A description of the test facilities that will be used for the combustion module R&D must also be included in the application. This must include a physical description of the facilities as well as details of the proposed experimental and computational methods, necessary instrumentation, and facility capabilities and limitations. Also include details on the ability to accurately quantify both steady and unsteady parameters at timescales relevant to RDEs. The description must also include details on the methods of acquiring performance estimates such as turbomachinery, cycle efficiency (with steady and unsteady flows), and combustor pressure gain.

Applications must include a TMP that shows current TRL, progressing to commercial deployment. Guidelines for the TMP preparation is provided via **Appendix DD**.

Anticipated Technology Readiness Level

Beginning of project: 2-3

End of project: 5

For this AOI, technology is expected to start at a TRL of 2–3 and conclude work at a TRL of 5. For TMP development, the pre-commercial prototype testing is expected to conclude at a TRL of 6.

Success Metric(s)

Successful projects under this AOI will demonstrate, through testing, a functional integration architecture with RDE and rotating turbomachinery that can maintain or surpass component and/or cycle efficiencies and levels of performance for state-of-the-art gas turbine engines for the purpose of land-based power generation. Additionally, the study must also provide a TMP that quantifies how the performance measured in the research test platforms will scale to a heavy frame (F-class or larger) or aeroderivative gas turbine engine.

APPENDIX N – AREA OF INTEREST 13: DATA GATHERING AND BASELINE ASSESSMENT FOR REGIONAL HYDROGEN HUBS

***** Area of Interest 13 is Not Funded at this time *****

Research Sought

The United States possesses the largest and most developed natural gas transportation and distribution network in the world. To address climate change, this network will need to rapidly evolve over the next several decades from being solely a supplier of natural gas to being a supplier of both natural gas and hydrogen gas. This transformation will require both near-term and longer-term R&D.

While many technical issues will need to be addressed, there is little doubt that the existing infrastructure of pipelines, compressor stations, and seasonal, subsurface storage can be retrofitted and redeveloped to carry hydrogen gas, whether blended with natural gas or pure.[27] Nonetheless, the uncertainties that remain in transforming the existing natural gas supply chain are daunting. The quantities of blue hydrogen[28] that will be needed, when and where, have not been fully assessed. In particular:

- In the near term, the cost of retrofitting specific infrastructure and storage versus new builds, combined with end-user needs, will determine whether blended or pure hydrogen is delivered to consumers. Longer term, climate change mitigation policy will predictably require carbon negative hydrogen to be produced and used pure or in higher blend ratios with natural gas; however, the dynamics of increasing hydrogen production, transport, and storage as part of future decarbonization efforts are still unclear.

- The differential between the delivered cost of blue and green hydrogen will dictate the relative distribution of these fungible commodities at regional and local scales. Currently, the cost of producing blue hydrogen is significantly lower than that for green hydrogen. While the cost of green hydrogen is projected to decline rapidly, there is considerable uncertainty as to how fast this will occur. In addition, published assessments have in general not considered regional/local variations in terms of production, transport, and storage capacity

[27] Janssen, D. (2020). "Hydrogen transport cost will vary on a case-by-case basis industry says," EURACTIV.com, https://www.euractiv.com/section/energy/news/hydrogen-transport-costs-will-vary-on-a-case-by-case-basis-industry-says/.

[28] *Blue Hydrogen* is hydrogen produced with today's technology from fossil resources such as natural gas, where the carbon emissions (CO_2) are captured and stored for a geologically significant period of time. *Green Hydrogen* is produced from non-fossil sources, employing renewable energy (e.g., direct solar and wind).

along with end user needs, nor further technology advancements beyond blue hydrogen[29] that could lower the cost of decarbonizing natural gas significantly while improving carbon efficiencies.

- The cost to produce and efficiently deliver blue hydrogen will be significantly impacted by the need to develop a strategy to potentially manage three or more distinct gas transportation systems for natural gas feed, pure hydrogen product, and/or additional hydrogen/natural gas product blend(s), and CO_2 or other storable form of carbon produced at the point of conversion. Wherever, along the hydrogen supply chain, decarbonization should occur, referred to as a hydrogen hub, requires careful assessment to achieve the lowest cost of delivered hydrogen, while maintaining supply chain operability, resiliency, flexibility, and future adaptability.

The objectives of this AOI are to (1) initiate a basin specific, regional consortium (including universities, state regulatory organizations, and industry stakeholders) to develop baseline data gathering and assessment for blue hydrogen potential, across the production, transportation, and storage value chain, and (2) assess the economic and carbon mitigation performance of possible current or future blue hydrogen supply chain elements ("hub" focused production, transportation within natural gas infrastructure, and large-scale, seasonal subsurface storage) for continued use of U.S.-produced natural gas as a feedstock.

Assessment elements should include, but are not limited to, existing regional H_2 production capacity, an assessment of regional expansion of H_2 production capacity allowing for near-term incremental technology improvement and longer term transformational production processes, techno-economic considerations for natural gas pipeline transportation, retrofitting, and the potential for future development of midstream infrastructure, and regional techno-economic considerations for long-term, large-scale subsurface storage in depleted oil and natural gas reservoirs and structurally appropriate saline storage formations.

Applicants shall provide a complete description of the proposed project addressing all Merit Review Criteria
Requirements for AOI 13 will be defined through future amendments to this FOA document.

Anticipated Technology Readiness Level

Beginning of project: 2–3

End of project: 3–5

[29] The term *Beyond-blue Hydrogen* is used here to refer to hydrogen that may be produced from natural gas in the future, using advanced technologies that may become available over the next few decades as a result of transformational and disruptive R&D. These technologies may capture carbon in storable forms other than CO_2, (e.g., solid carbon) and could significantly reduce carbon emissions per unit of H_2 delivered, by substituting renewable forms of energy (e.g., direct solar, etc., or electricity derived there from) across the hydrogen supply-chain and the adoption of other next-generation, natural gas-to-hydrogen technologies still at an early stage of development.

This data gathering and baseline effort begins as a proof-of-concept to validate the viability of regional hubs for hydrogen production, transportation, and storage. At project end, the effort will result in a regional assessment of multiple sources of data to develop further characterization or technology development pathways in preparation for large-scale demonstration across the hydrogen value chain noted above.

Success Metric(s)

The completed modeling tool will be considered successful if it is of sufficient detail to enable its use by DOE to:

- Assess the benefits and challenges of technologies for future carbon-negative hydrogen technologies for the production, transportation, and storage being developed with funding from DOE and or other organizations, where appropriate.

- Provide input for the development of a comprehensive Beyond Blue Hydrogen R&D Plan, including a roadmap for large-scale scale natural gas decarbonization, detailing how hydrogen and CCS infrastructure can be scaled up over time.

- Identify and evaluate future development sites for the scale-up and demonstration of hydrogen hubs located in major natural gas producing regions of the United States.

Technology Maturation Plan

Requirements for AOI 13 will be defined through future amendments to this FOA document.

APPENDIX O – AREA OF INTEREST 14: CLEAN HYDROGEN PRODUCTION AND INFRASTRUCTURE FOR NATURAL GAS DECARBONIZATION

*******AOI 14 was previously issued*******

Research Sought

Advanced and mature commercial technologies exist for producing hydrogen from natural gas. Similarly, advanced and mature CO_2 capture technologies are also commercially available. The coupling of these hydrogen production and CO_2 capture technologies will become the mainstay for the deployment of clean hydrogen derived from natural gas combined with CCUS over the remainder of this decade. Due to inherent costs and efficiency limitations, however, existing technologies alone will likely not be sufficient to address the projected demand for a direct alternative to decarbonized natural gas for applications such as industrial process heat and power generation, home heating and fuels, and other applications where electrification is not practical. In addition, hydrogen for the manufacture of chemicals, steel, cement, liquid fuels (including advanced biofuels), and other products will also be needed as these industries accelerate the pace of their decarbonization efforts.

Under FECM's Office of Resource Sustainability, the Natural Gas Decarbonization and Hydrogen Technologies R&D Program supports the current administration's goal of net-zero carbon emissions by 2050 through transformation of the U.S. natural gas industry from being a direct supplier of natural gas to also being a strategic supplier of carbon-free hydrogen gas derived from the nation's plentiful natural gas resources. The focus of this AOI is the advancement of transformational and disruptive technologies for clean hydrogen production with the greatest decarbonization benefits for fuels and chemicals derived from natural gas. This research effort supports the Program's long-term objective of moving the nation toward net-zero life cycle GHG emissions while radically reducing the cost of producing clean hydrogen. This research effort supports DOE's Hydrogen Energy Earthshot Initiative launched in 2021, which targets a $1 production cost per kilogram of clean hydrogen in one decade (by 2030). To achieve the above-stated objective, R&D proposals are sought to identify and develop new natural gas-to-hydrogen process concepts employing novel conversion, separation, and heat and mass integrated technologies.

Concepts for technology development in this area will be at TRL 4+ level with existing successful demonstration of laboratory integration of the basic technology components now ready to be scaled up into a configuration that matches what will be the final commercial hydrogen production application. Demonstrated technologies shall be capable of long-term stable operation adequate to support economic analysis for comparison to Hydrogen Shot goals for costs and CO_2 emission targets. Technology concepts in this area will include methods that are ready to have their basic components integrated and validated in a manner consistent with what will be used in the eventual commercial environment. These technologies must include a clear

mechanism or pathway for capture of the carbon or any associated emissions that are produced, documented through techno-economic and life cycle analyses.

Under AOI 14, there are three Sub-topics:

Sub-topic 14a: Methane pyrolysis/decomposition, in situ conversion, or cyclical chemical looping reforming.

14ai: Pyrolysis
Proposals for this area will consider hydrogen production through methane pyrolysis or methane decomposition through methods such as thermal pyrolysis, thermal catalytic methods, molten mediators, or mechanical compression processes capable of producing hydrogen and solid carbon. These processes must be capable of producing non-hazardous carbon suitable for environmentally safe indefinite storage, as well as pure hydrogen. Research in this area may focus on challenges in methane pyrolysis, such as scaling up mechanical compression approaches with long-term reliability, application of thermal decomposition at scale, or means of continuous carbon product separation. Products should include cost-model overviews and viably identifiable market pathways.

14aii: In Situ Conversion – Thermochemical
Proposals for this area will consider any thermochemical means for the production of hydrogen from natural gas at the wellhead and occurring in the reservoir, such that only hydrogen gas is brought to the surface with the carbon remaining in-place. Research in this area needs to focus on ways to enable efficient processes that are safe, environmentally benign, and cost-effective.

14aiii: In Situ Conversion – Biological
Proposals considered for this area will use biological science and technology to enable the biochemical creation of hydrogen from natural gas using the reservoir as the reaction vessel, such that only hydrogen gas is brought to the surface with the carbon remaining in-place. Research in this area will potentially consider genetic modification, novel methods for bio-reaction stability and monitoring, and means for ensuring durability of the geological features in the reservoir relevant to the reaction time scale. The benefits of using a geological reaction vessel for relatively slow conversion processes are most evident, but considerations for the containment of all biological processes and demonstration of no negative environmental impacts must be rationalized while enabling an effective means of carbon product separation and hydrogen gas extraction.

14aiv: Cyclical Chemical Looping Reforming
Proposals for this area will consider processes targeting hydrogen production that are capable of using “gas switching” methods for cyclic operation through the controlled change of flow for gaseous reactants. These processes will cycle the method of operation in single reactors rather than rely on methods of fluidized mass transport of a solid oxygen carrier between multiple reactors. Research in this area may focus on mitigation of the attrition of

sorbents, optimizing the gas cycling process, maximizing heat transfer rates, or incorporation of product gas purification/separation and capture of the CO_2 stream.

14av: Other Areas Not Specifically Identified that Meet Objectives of AOI 14a
Proposals for this area could include, but are not limited to, concepts that use photocatalytic reforming, polymerization methods to store carbon, or methods that produce a hydrogen carrier as the end-product directly. Research for any of these areas will vary based on the proposed method but must meet the overall objectives of this AOI.

Sub-topic 14b: Hydrogen Production from Produced Water
Conventional oil and natural gas resources are directly connected with the use of water, where water makes up the majority of the fluid used to drill wells and fracture oil- or gas-bearing formations. Water is also an important co-product that is brought to the surface with the oil and natural gas, known as produced water. Depending on the chemistry of the rocks in the targeted reservoirs, produced water may contain many different chemical constituents (i.e., dissolved mineral salts), or it may be mixed with organic compounds (i.e., acids, waxes, and mineral oils). It may also be mixed with inorganic metals and byproducts, or with trace amounts of heavy metals and naturally occurring radioactive materials. This research area is focused on a demonstration of technologies for producing hydrogen from the processing of produced water and mineral substances and on transporting the resultant hydrogen using existing energy infrastructure.

****** Sub-topic 14c is not funded at this time ******

Sub-topic 14c: Additional Transformational Clean Hydrogen Production Methods

14ci: Non-Equilibrium Plasma and Microwave-Assisted Conversion
Methods that use any form of non-thermal equilibrium activation of natural gas are of interest in this technical area, such as, but not limited to, gliding arc, dielectric barrier discharge, and microwave-assisted reforming processes. Non-equilibrium methods have potential for significantly reducing energy consumption through a precise focus of energy toward dissociation of only the targeted bonds without requiring bulk heating of the reactor. Research in this area will focus on evaluation of new non-equilibrium methods and optimization and adaptation toward the specific bond energies in various natural gas compositions. Carbon product separation, its stability, and its long-term environmental safety for perpetual storage or utilization must also be considered.

14cii: Mechano-Chemical Conversion
Processes for consideration will utilize some form of mechanical compression or any form of highly localized disturbance in the natural gas medium that creates significant difference in density or temperature to dissociate the bonds in natural gas. Processes can include, but are not limited to, high-speed rotor methods that create standing shock waves. Research in this area will focus on new methods for mechanical manipulation, thermal and mass transport optimization, and novel manufacturing processes for creation of stable mechano-chemical

reactors with long-term reliability. Carbon product separation enabling continuous use must also be considered.

The projects selected from this AOI will help DOE better understand the full potential and limitations of new and emerging science and technology as they relate to the conversion with decarbonization of natural gas to hydrogen, enabling DOE to better focus future hydrogen R&D efforts toward accelerating the development of these climate-critical technologies.

Technical Elements that Must be Included in Applications

Applicants shall provide a complete description of the proposed project addressing all Merit Review Criteria.

Anticipated Technology Readiness Level

Beginning of project: TRL 4

Projects awarded under this AOI shall have already demonstrated analytical and experimental critical function and/or characteristic proof-of-concept and, therefore, be at a starting TRL of 4–5.

End of project: TRL 5-6.

Success Metric(s)

- DOE's program efforts in this space would be considered successful if DOE can analyze project results to quantify the potential of the proposed technology for significant improvement in the economic performance measured against those established by the DOE Hydrogen Shot Goal of $1 per kilogram of clean hydrogen production by 2030. Applicants should clearly present the specific elements of their proposed technology that directly reduce production costs while maintaining net-zero carbon emissions throughout the entire lifecycle of the proposed process.
- Project performers should report techno-economic modeling in a manner that enables direct comparison of cost and efficiency to a relevant baseline. The data reported must be presented with sufficient detail to enable additional analysis by third party organizations or DOE. As part of these analyses, performers should identify critical R&D elements required to scale their technology up to high-volume industrial scale and/or down to a low-volume modular scale.
- Performers must also provide an analysis that sufficiently quantifies the entire emissions profile from natural gas production to hydrogen generation in order to show how the process can satisfy the Hydrogen Shot CO_2 emissions requirements. This analysis must consider emissions not only from chemical reaction and any associated process energy requirements, but also from any ancillary processes such as feedstock transport, pre-reforming, or contaminant removal. Any coincident systems associated with CO_2 or solid

carbon capture, storage and/or utilization must also be accounted for.

- Report of project findings by project performers in a manner that enables techno-economic modeling and analysis, which could be executed by project performers, by DOE, or third-party independent entities. Data reported by the project performer must be transparent enough to enable analysis by third parties or independent organizations.
- Presentation of clear and concise results that demonstrate the advancement of the technology from TRL 4 to at least TRL 5. Suggestions for specific research areas for advancement can be found in the Sub-topics listed in this AOI.

Technology Maturation Plan

A TMP is not required with the application but is required 90 days after award, with a final TMP due within 90 days of project completion.

Workforce Readiness Plan

Workforce readiness plan is not required.

Questionnaires

(1) A completed "Environmental Justice Questionnaire" will be required for this AOI as an attachment to the final report. (See **Appendix FF** for the Questionnaire)

(2) A preliminary "Environmental Justice Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.) (See **Appendix FF** for the Questionnaire)

(3) A completed "Economic Revitalization and Job Creation Questionnaire" will be required for this AOI. (See **Appendix GG** for the Questionnaire)

(4) A preliminary "Economic Revitalization and Job Creation Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.) (See **Appendix GG** for the Questionnaire)

APPENDIX P – AREA OF INTEREST 15: TECHNOLOGIES FOR ENABLING THE SAFE AND EFFICIENT TRANSPORTATION OF HYDROGEN WITHIN THE U.S. NATURAL GAS PIPELINE SYSTEM

*******AOI 15 was previously issued*******

Research Sought

As the demand for hydrogen as an energy carrier increases, a means for transporting (hydrogen) fuel between production (generation) and end-use locations (consumption) will be necessary. Currently, gaseous hydrogen produced for industrial use is transported largely by either tube trailer trucks or dedicated pipelines, while liquid hydrogen is moved by cryogenic tanker trucks. Liquid hydrogen shipping is further being considered as a means for global trade and the transportation of larger volumes between countries using seagoing vessels in a fashion similar to liquefied natural gas (LNG).

Because of hydrogen's low molecular weight and high diffusivity, hydrogen leak rates across these various transportation infrastructures are concerns from both resource loss and global warming potential perspectives. Atmospheric hydrogen can indirectly generate a warming effect in the atmosphere by reacting with other elements in a manner that produces GHGs or extends their life. The magnitude of hydrogen's negative effects on warming is not well-understood but is generally accepted as being much less than its benefits as a means of decarbonization. Current estimates of hydrogen release rates from infrastructure vary widely. Industry estimates range from less than 1% from gaseous pipelines to 4% from gaseous tube trailer pathways, and 10–20% from the liquid hydrogen supply chain, with expectations that liquid hydrogen release rates would decline to 4–5% by 2030 through system optimization with increased utilization.

Beyond GHG concerns, while trucking may be feasible for short distances and smaller volumes, pipelines are more economical for longer distance, larger volume transport. Existing U.S. natural gas pipeline infrastructure may have the potential to accommodate the bulk transportation of hydrogen to further decarbonize pipeline transportation systems. Blending hydrogen into the natural gas carried in the existing pipeline networks may be an option for delivering mixed gas blends or pure hydrogen to markets, using separation and purification technologies downstream to extract hydrogen from the natural gas blend near the point of end-use.

However, utilizing the existing natural gas pipeline system presents a number of challenges, primarily related to the differences between hydrogen and methane molecules and their influence on pipeline infrastructure and flow control equipment materials. Key examples include hydrogen embrittlement of metals leading to increased risk of rupture or leaks, and higher leakage rates of hydrogen, either through permeation or escape via seals and joints. Additional technical operating challenges include the potential impact of hydrogen blend levels on gas

metering systems and pipeline system sensors and the potential for increased safety risks due to hydrogen's broader range of conditions supporting ignition.

Blend percentages vary greatly by region/country from less than 1% to 30%. Up to 15% may feasibly be transported through natural gas pipelines without significant modifications to existing infrastructure or significant detrimental effects. However, the appropriate blend concentration may vary significantly among pipeline network systems or end-uses and natural gas compositions and must be assessed on a case-by-case basis.

To realize the decarbonization benefits of hydrogen transport within natural gas systems, leak detection and mitigation must be more fully realized to minimize or eliminate leaks and system losses. Further research is required to determine the effectiveness of various leak detection technologies for hydrogen-natural gas mixtures and assess leakage rates for higher operating pressures (e.g., transmission level) and/or blends greater than 20% hydrogen.

Hydrogen leakage requires accurate quantification and effective mitigation. Evaluation of the global warming impacts of the hydrogen supply chain will require measurements in outdoor environments at the parts per billion (ppb) level, which is not feasible with commercially available systems to date. Current sensors have been designed to detect hydrogen releases at a parts per million (ppm) scale, for use in mitigation of safety risks rather than for quantification on a ppb scale for assessment of environmental impacts.

The objective of AOI 15 is to seek research to develop cost-effective methods for technologies for:

- The effective bulk blending of hydrogen with natural gas and using the natural gas pipeline system to transport hydrogen from production centers to end-users, including laboratory- and field-testing to determine the most effective blending ratios given a wide range of assumptions regarding equipment characteristics, natural gas characteristics, and pipeline conditions.
- Non-emitting technologies for separating hydrogen from hydrogen and natural gas blended streams for end-use applications.
- Mitigating hydrogen leaks in pipeline infrastructure and handling equipment, including new materials development designed to reduce the capability of hydrogen to leak from otherwise methane-tight systems.
- Mitigating the impact of hydrogen concentration on sensing and measurement equipment used within the natural gas pipeline system.
- Reducing or mitigating materials fatigue and failure, up to and including the effects of hydrogen embrittlement, and new materials development.
- Hydrogen sensor development at ppb (sub-ppm) level for more accurate hydrogen leakage quantification via highly sensitive materials and sensor devices.
- Long-distance and wide-area sensing outdoors / in the open for hydrogen leak quantification and hydrogen leakage assessment.
- Best practices and guidance to assess life cycle emissions of real-world deployments of

clean hydrogen.
- Analysis of most efficient hydrogen production, blending and separation points along the supply infrastructure to allow for the effective large-scale deployment of clean hydrogen.

Technical Elements that Must be Included in Applications

Applicants shall provide a complete description of the proposed project addressing all Merit Review Criteria. Applicants should avoid duplication with ongoing efforts and will be expected to coordinate closely with HFTO-funded activities, including the H-Mat consortium and the HyBlend project selected through the hydrogen@Scale initiative (see H-Mat: https://h-mat.org/ and HyBlend: https://www.nrel.gov/news/program/2020/hyblend-project-to-accelerate-potential-for-blending-hydrogen-in-natural-gas-pipelines.html

Anticipated Technology Readiness Level

Beginning of project: TRL 4

This AOI focuses on the adaptation of existing natural gas pipeline transportation systems to integrate considerations for hydrogen blending and transportation. Projects awarded in this AOI will be expected to have proof-of-concept validation completed and be prepared to integrate system components with the end goal of achieving a working prototype ready for field testing in a relevant environment by project end.

End of project: TRL 6

Success Metric(s)

- By 2025, projects will develop a comprehensive understanding of the maximum amount of hydrogen that can be safely handled by the existing natural gas pipeline system, including with respect to all relevant variables and as related to non-pipeline components and equipment.
- By 2025, the program will have developed a comprehensive understanding of the performance limits of sensing, measurement, and control systems across a range of hydrogen blend ratios and new hydrogen detection and measurement systems that enable the safe and effective operation of natural gas pipelines handling blends of hydrogen and natural gas.
- By 2025, develop best practices and guidance to assess life cycle emissions of real-world deployments of clean hydrogen.
- By 2027, deploy hydrogen sensor development at ppb (sub-ppm) level for more accurate hydrogen leakage quantification via highly sensitive materials and sensor devices.
- By 2027, deploy long-distance and wide-area sensing outdoors / in the open for hydrogen leak quantification and hydrogen leakage assessment.
- By 2030, the program will have developed a significantly improved understanding of

fundamental hydrogen interactions with plastic and metal materials as well as a comprehensive understanding of the performance limits of compression systems across a range of hydrogen blend ratios.

- By 2035, the program outcomes will include novel pipeline tubulars and components that are less prone to leaks or hydrogen damage and safe, cost-effective additives to enhance hydrogen carrying capacity of natural gas pipelines and related infrastructure.

Technology Maturation Plan

A TMP is not required with the application but is required 90 days after award, with a final TMP due within 90 days of project completion.

Workforce Readiness Plan

Workforce readiness plan is not required.

Questionnaires

(1) A completed "Environmental Justice Questionnaire" will be required for this AOI as an attachment to the final report. (See **Appendix FF** for the Questionnaire)

(2) A preliminary "Environmental Justice Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.) (See **Appendix FF** for the Questionnaire)

(3) A completed "Economic Revitalization and Job Creation Questionnaire" will be required for this AOI. (See **Appendix GG** for the Questionnaire)

(4) A preliminary "Economic Revitalization and Job Creation Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.) (See **Appendix GG** for the Questionnaire)

APPENDIX Q – AREA OF INTEREST 16: FUNDAMENTAL RESEARCH TO ENABLE HIGH VOLUME, LONG-TERM SUBSURFACE HYDROGEN STORAGE

*******AOI 16 was previously issued*******

Research Sought

Solution-mined salt caverns, depleted natural gas or oil reservoirs, and saline aquifers are all currently used for natural gas storage and provide significant economies of scale, high-efficiency (the quantity of hydrogen injected divided by the quantity that can be extracted), low operational costs, and low-land costs. These characteristics mean that they are likely to be the lowest-cost option for bulk hydrogen storage as hydrogen production from natural gas continues to accelerate.

Salt caverns have been used for hydrogen storage by the chemical sector in the United States since the 1980s. They are typically low-cost, efficient, and have a low risk of contaminating the hydrogen that is stored. Their high pressures enable high discharge rates, making them attractive for a variety of industrial applications. The United States has the largest salt cavern hydrogen storage system currently in operation—it can store around 30 days of hydrogen output from a nearby SMR unit (between 10,000–20,000 tonnes of hydrogen) to help manage the supply and demand for refining and chemicals.

Depleted oil and gas reservoirs (and related porous media) typically provide larger storage volumes than salt caverns, but they can also be geologically complex and contain contaminants that would have to be removed before the hydrogen would be suitable for end-use applications. Saline aquifers are the least mature of the three geological storage options, and there is mixed evidence for their suitability. As with oil and gas reservoirs, natural barriers trap much of the hydrogen deep underground. However, reactions with microorganisms, in situ fluids, and formation rock minerals can lead to losses of hydrogen. Though not previously investigated for commercial use with pure hydrogen, many saline aquifers would also incur delineation, characterization, and development costs. The feasibility and cost of storing hydrogen in depleted reservoirs and saline aquifers have not fully been validated on a commercial scale.

The objective of AOI 16 is research into the fundamental concepts that will enable high-volume, long-term subsurface bulk hydrogen storage, specifically:

- Characterization of the long-term effects of hydrogen presence on formation fluids and reservoir rock (including microbial interactions) in depleted oil and natural gas reservoirs, saline formations, and salt structures for the purpose of evaluating storage permanence and long-term hydrogen extraction potential.
- Assessment of the effects of long-term hydrogen exposure on wellbore materials and equipment, including cement, casing, tubing, and other injection/extraction equipment.
- Basin-specific hydrogen storage capacity estimates for large-scale, long-term hydrogen

storage, coupling information on hydrogen production potential to establish the viability of hydrogen hubs for regional hydrogen production, transportation, and subsurface storage.
- Assessment for the potential of porous media or other "hard rock" hydrogen storage in areas where suitable depleted oil and natural gas reservoirs, saline formations, or salt structures exist for long-term storage in proximity to industrial or power sector end-users.

Further, the data generated from these studies and assessments will be utilized to accelerate the development of large-scale subsurface hydrogen storage projects to demonstrate the long-term storage and extraction efficiency.

Technical Elements that Must be Included in Applications

Applicants shall provide a complete description of the proposed project addressing all Merit Review Criteria. Applicants should avoid duplication with ongoing efforts and will be expected to coordinate closely with HFTO-funded activities, including the hydrogen@Scale initiative (see: https://www.energy.gov/eere/fuelcells/hydrogenscale).

Anticipated Technology Readiness Level

Beginning of project: TRL 4

Projects proposed in this AOI shall have completed proof-of-concept validation (TRL 4) and progress through an integrated data assessment in preparation for field-scale development (TRL 6) by the end of the project.

End of project: TRL 6

Success Metric(s)

- By 2024, projects will have characterized the impact of hydrogen on formation fluids and reservoir rock on a laboratory scale and identify appropriate mitigation solutions in preparation for scale-up activities and field-based evaluations.
- By 2025, projects will complete a commercial-scale evaluation of bulk hydrogen storage potential in basins with significant capacity to convert natural gas into large volumes of hydrogen for long-term storage to maintain availability for large-scale industrial and power sector use.
- By 2025, projects will develop a comprehensive understanding of the effects of long-term hydrogen exposure on wellbore materials and equipment, with mitigation solutions identified.

A better understanding of these fundamental processes along with preliminary evaluations of long-term hydrogen storage potential will be coupled with future field-based research focused on the development of large-scale hydrogen hub projects. These hub projects are targeted

towards the safe, efficient conversion of natural gas into hydrogen, the safe, emissions-free transportation of hydrogen using existing natural gas infrastructure to end-users and long-term subsurface storage facilities, and the injection, storage, and extraction of hydrogen from subsurface reservoirs with the greatest capacity for safety and efficiency by 2035.

Technology Maturation Plan

A TMP is not required with the application but is required 90 days after award, with a final TMP due within 90 days of project completion.

Workforce Readiness Plan

Workforce readiness plan is not required.

Questionnaires

(1) A completed "Environmental Justice Questionnaire" will be required for this AOI as an attachment to the final report. (See **Appendix FF** for the Questionnaire)

(2) A preliminary "Environmental Justice Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.) (See **Appendix FF** for the Questionnaire)

(3) A completed "Economic Revitalization and Job Creation Questionnaire" will be required for this AOI. (See **Appendix GG** for the Questionnaire)

(4) A preliminary "Economic Revitalization and Job Creation Questionnaire" will also be required with applications and evaluated for this AOI. (The preliminary version will later be updated in the final report.) (See **Appendix GG** for the Questionnaire)

APPENDIX R – AREA OF INTEREST 17: HYDROGEN COMPRESSION FOR PIPELINE TRANSPORTATION AND SUBSURFACE STORAGE

***** Area of Interest 17 is Not Funded at this time *****

Research Sought

This AOI seeks to develop turbine-based hydrogen compression technology for pipeline hydrogen transportation and subsurface hydrogen storage. The objective of this AOI is to progress the technical understanding of hydrogen compression, determine technology gaps for existing hydrogen compression technology, and develop and test improved compression turbomachinery for one of two applications of interest:

AOI 17a: Compression of Hydrogen for Pipeline Transportation
AOI 17b: Compression of Hydrogen for Subsurface Storage

Each of these applications has different requirements for pressure, flow rate, and operational mode. Pipeline compressors operate at 30–90 bar with high flow rates and continuous operation. Subsurface storage will likely have intermittent or cycling operation with lower flow rates. Underground storage pressures range from 45–155 bar. The objective of this AOI is to advance hydrogen compression technologies for these discrete applications and conduct an engineering-scale prototype test of a full-scale compression system.

Requirements for AOI 17 will be defined through future amendments to this FOA document.

Anticipated Technology Readiness Level

Beginning of project: 5

End of project: 6-7

This AOI will advance hydrogen compression systems for pipeline hydrogen transportation and subsurface storage from a TRL of 5 to a TRL of 6–7 through engineering-scale prototype testing.

Success Metric(s)

Prototype demonstration test of a full-scale, turbine-based hydrogen compression system to demonstrate a TRL of 6 or higher over a range of advanced performance conditions.

APPENDIX S – AREA OF INTEREST 18: MATURATION OF TECHNOLOGIES FOR GASIFICATION-BASED CLEAN HYDROGEN SYSTEMS

AOI Issue Date	09/12/2023
Submission Deadline for Full Applications	11/14/2023

AOI 18a: Oxygen-Generation Component/ Air Separation Unit

DOE Share (80%)	$5,000,000 - $7,000,000
Cost Share (20%)	$1,250,000 - $1,750,000
Anticipated No. of Awards	2
Maximum Period of Performance	24 Months (Single Phase/ Single Budget Period)

AOI 18b: Feedstock Delivery Component

DOE Share (80%)	$3,000,000 - $4,000,000
Cost Share (20%)	$750,000 - $1,000,000
Anticipated No. of Awards	2
Maximum Period of Performance	24 Months (Single Phase/ Single Budget Period)

Research Sought

Solid fueled gasification-based systems for electricity production and liquid fuels production based on coal and petcoke feedstocks are mature at scale with multiple commercial examples deployed over the past decades. Those systems have tended to use high-temperature, oxygen- or steam-blown, pressurized, entrained-flow gasification at relatively large scale, or moving bed or fixed bed choices such as Lurgi gasifiers for syngas production for methanol or Fischer-Tropsch (FT) fuels synthesis. In the biomass gasification field, smaller-sized moving bed or fixed bed gasifiers and fluidized bed gasifiers comprise the vast majority of gasifiers used, given their relative flexibility in handling varying feed streams and suitability to the moderate sizes needed for typical applications.

However, high-temperature, oxygen- or steam-blown, pressurized, entrained-flow or fluidized bed gasification of multiple biomass and waste feed streams, consisting of legacy coal waste, municipal solid waste, and/or non-recyclable plastics, has been advocated as an important area of focus for R&D, considering the higher efficiency and reaction intensity of entrained gasification, plus the emissions and environmental benefits of utilizing biomass and liability waste materials. DOE/NETL have made inroads into this area in supporting R&D of highly efficient modular gasifiers, feeding of lower quality fuels including biomass/waste blends, and lower cost air separation for modular systems, among others. Certain innovative gasifiers, air separation, and gas separations technologies have been developed and advanced at bench scale.

The current challenge is maturation of promising DOE and industry-supported gasification and supporting technologies beyond bench scale to prototypes and small pilots, setting the stage for

eventual demonstrations at commercial scale and ultimate commercialization. Accordingly, this AOI seeks proposals for technology scale-up projects that will advance viable gasification energy system component technologies currently proven at bench scale (TRL 4) to demonstration of prototypes or small pilots (TRL 6), as part of a plausible maturation path leading to commercialization.

Specifically, this AOI is interested in the **oxygen generating component** (under **18A**) and the **feedstock delivery component** (under **18B**) of a gasifier system. The feedstock delivery component should be able to measure the heat content of the feed and have a control system that allows for adjustment of the feed speed or oxygen flow rate as a function of the BTU. This project should culminate with an engineering-scale prototype of the component that is validated in a relevant environment.

Technical Elements that Must be Included in Applications

The Applicant must clearly document that the technology is advanced to a robust bench-scale technology maturity level, and suitable for progression beyond bench-scale to prototype or small pilot work. The technology must have legitimate application in modular gasification-based energy systems, preferably for clean hydrogen production or liquid fuels production with net-zero carbon emissions performance. The Applicant must identify the gasifier and system specs for which their component is applicable, and the size of the component proposed. The feedstock component should be designed for an entrained flow or fluidized bed system.

The application must provide a logical progression of activities which will advance the technology from the current state of technological readiness through to a small pilot scale demonstration.

All applications must include an R&D Community Benefits Plan (CBP), which includes: (1) a Diversity, Equity, Inclusion, and Accessibility (DEIA) section; (2) a completed Environmental Justice (EJ) Questionnaire; and (3) a completed Economic Revitalization and Job Creation (ERJC) Questionnaire for evaluation under Merit Review Criterion (MRC) 4. See **Appendices HH, FF, & GG** for guidance on preparing these documents.

Research Scope and Attributes that are Not of Interest

This AOI is specifically interested in the scale-up of the specified gasification system components, not in the gasifier itself.

R&D specifically not of interest includes:

- Any current commercially available technologies
- Gasifiers themselves
- Technologies that do not have a gasification system connection
- Components of the gasification system other than those specified
- Feedstock delivery components connected to air blown, fixed bed, or moving bed gasifiers

- Tar cracking systems

Applications that include aspects listed above, which have been identified as not being of interest, will be considered non-responsive and will not be evaluated.

Anticipated Technology Readiness Level

Beginning of project: 4
Refer to **Appendix CC** for NETL Interpretations of DOE Technology Readiness Levels. The proposed work must not require further bench-scale development. Work should begin with high-fidelity, near-prototype study.

End of project: 6
Project success will be ensured by advancing the TRL from the initial starting level to 6, implying successful small pilot demonstration was accomplished. Verifiable advancement toward commercialization is essential to project success.

Success Metric(s)

A successful project will mature a working prototype of the specified component to gather operating hours and lessons learned. It will demonstrate a component that has the potential to scale-up under realistic conditions.

Technology Maturation Plan

A full technology maturation plan (TMP) will be required with application.

Workforce Readiness Plan

A Workforce Readiness Plan will not be required as a deliverable in the SOPO for this AOI.

Questionnaires

- A preliminary "Environmental Justice Questionnaire" will be required with applications as part of the CBP and evaluated for this AOI. The preliminary version will later be updated in the final report. See **Appendix FF** for the Questionnaire.
- A preliminary "Economic Revitalization and Job Creation Questionnaire" will also be required with applications as part of the CBP and evaluated for this AOI. The preliminary version will later be updated in the final report. See **Appendix GG** for the Questionnaire.

APPENDIX T – AREA OF INTEREST 19: ADVANCED SENSORS TO ENABLE GASIFICATION TO PROVIDE CLEAN HYDROGEN MEETING HYDROGEN-SHOT COST PARAMETERS

AOI Issue Date	09/12/2023
Submission Deadline for Full Applications	11/14/2023
DOE Share (80%)	$500,000
Cost Share (20%)	$125,000
Anticipated No. of Awards	3
Maximum Period of Performance	24 Months (Single Phase/ Single Budget Period)

Research Sought

In the emerging hydrogen economy, increased utilization of modular gasification-based energy systems for clean hydrogen, liquid fuels, or chemicals production with net-zero carbon emissions performance is expected. Such gasification systems will be fueled with challenging multiple solid waste feedstocks including waste plastics, sustainable biomass, municipal solid waste (MSW), and waste coal. Flexible gasification of these non-traditional mixed feedstocks will chart new territory, in which the impacts of these varied and possibly contaminated materials in gasification performance and fouling of gasifiers is not well understood. Robust and durable sensors will be essential to developing, operating, and optimizing these systems.

DOE/NETL have been supporting development of technology for advanced sensors for deployment in high temperature and corrosive/erosive environments within energy systems. Advanced sensors are needed for reliable operation of energy conversion systems and hence lower cost of energy. Sensors in gasification processes have been shown to be a critical component of the system. An example of the issues faced in gasification systems in such difficult environments is represented by the failures encountered with the original configuration of the syngas cooler in the Polk Power IGCC station.[30] Originally, heat exchangers were located just after the convective syngas coolers to recover additional heat by warming clean syngas to the combustion turbine. However, fly ash deposits formed on the heat exchanger tubes on the raw gas side, which eventually led to under-deposit corrosion cracking of the tubes. Tubes began failing, contaminating the syngas which resulted in ash deposits on and damage to turbine blades. The exchangers were too expensive to repair and were eventually removed. Capabilities for measuring surface temperatures within vessels and real time knowledge of fouling would be invaluable for monitoring for such issues. New developments for sensors in gasification systems have potential to overcome the limited applicabilities of conventional sensors in tackling these problems. Repurposing and leveraging experience in earlier R&D for coal boiler sensors could assist with improving reliability, availability, and maintainability (RAM) in gasification systems.

[30] "Tampa Electric Polk Power Station Integrated Gasification Combined Cycle Project Final Technical Report, August 2002. https://netl.doe.gov/sites/default/files/netl-file/TampaFinal.pdf

NETL's recent R&D work on advanced sensors has included testing of wireless temperature and corrosion sensors inside coal-fired boilers where they are subjected to both combustible gases and ash deposition, and testing of ultrasonic sensors for revealing real-time temperature profiles in operational transitions. The information such sensors can gather is invaluable for monitoring performance of and understanding dynamic processes occurring in these energy systems, thereby enabling more optimized operations and maintenance, while also increasing system availability and efficiency.

This AOI seeks proposals for a wireless sensing technology to continuously monitor integrity of gasifier internal components, which operate in high temperature reducing and corrosive atmospheres, to maximize availability and dispatchability, thus providing low operating cost and progress towards clean hydrogen at $1/kg. This AOI envisions clean hydrogen production from gasification-based systems using fuel mixtures containing one or more of the following: (1) coal waste, (2) biomass, (3) waste plastics, (4) municipal solid waste (MSW), or (5) industrial waste. Clean hydrogen must be adequate for co-feeding into a coal-fired boiler. Sensing of portions of the gasification system having fouling/slagging concerns is in primary scope.

This AOI directly addresses the mandate from The Senate in FY23, which included language on wireless sensor systems for coal-fired power generation that was adopted by the House, as follows: [The Joint Explanatory Statement] "provides $1.5M to accelerate development and deployment of wireless sensor systems for coal fired power generation in order to improve generative efficiency, reduce emissions, and lower maintenance costs."

Technical Elements that Must be Included in Applications

The intent is that sensors potentially capable of harsh gasification environments and which exceed performance of existing technology will be investigated for novel use in gasification systems for clean hydrogen production using the challenging mixed feedstocks described above. Previously developed sensors technology from DOE/NETL's efforts in the Transformative Power Generation and other programs could be strong candidates for possible re-application in the gasification-based clean hydrogen production context of interest in this AOI.

Although technologies supported in this AOI must be capable of handling feedstocks as specified, the technology must also be capable of supporting a coal-fired power generation system and gasification-based energy systems.

The technology must be a wireless sensing system.

All applications must include a Community Benefits Plan (CBP), which includes: (1) a Diversity, Equity, Inclusion, and Accessibility (DEIA) section; (2) a completed Environmental Justice (EJ) Questionnaire; and (3) a completed Economic Revitalization and Job Creation (ERJC) Questionnaire for evaluation under Merit Review Criterion (MRC) 4. See **Appendices HH, FF, & GG** for guidance on preparing these documents.

Research Scope and Attributes that are Not of Interest

Sensing techniques that are only effective for elements operating in an oxidizing atmosphere are not of interest. Gasifiers produce reducing gases with high hydrogen concentration in addition to high carbon monoxide concentration.

Anticipated Technology Readiness Level

Beginning of project: 3-4
Proposed R&D should leverage sensing technology that has already advanced to a TRL level of 3 at a minimum.

End of project: 4-5
Project success will be ensured by advancing the TRL to 4 or 5. The implication is that the sensing technology examined had been previously validated as a stand-alone component at TRL 3, or possibly previously validated at TRL 4 in a system context of a non-gasification-based energy cycle (such as a conventional coal-fired boiler for electricity production), but through project scope will be advanced to/validated at TRL 4 or 5 in the context of the gasification-based hydrogen-producing system utilizing the challenging mixed solid feedstocks.

Success Metric(s)

Research funded under this FOA would be successful if it enables a method to assess real-time integrity of metallurgical components inside of gasifiers that are normally avoided because of high risk of failure. Confidence in installing heat-recovery tubes into gasifier cooling zones could lead to efficiency gains and cost reductions in clean hydrogen generation systems.

Technology Maturation Plan

A technology maturation plan (TMP) will be required as a deliverable 90 days after award.

Workforce Readiness Plan

A Workforce Readiness Plan will not be required as a deliverable in the SOPO for this AOI.

Questionnaires

- A preliminary "Environmental Justice Questionnaire" will be required with applications as part of the CBP and evaluated for this AOI. The preliminary version will later be updated in the final report. See **Appendix FF** for the Questionnaire.
- A preliminary "Economic Revitalization and Job Creation Questionnaire" will also be required with applications as part of the CBP and evaluated for this AOI. The preliminary version will later be updated in the final report. See **Appendix GG** for the Questionnaire.

APPENDIX U – AREA OF INTEREST 20: DIGITAL TWINS FOR ADVANCED MONITORING, DETECTION, AND SECURITY FOR INTEGRATED HYDROGEN-BASED SYSTEMS WITH CARBON CAPTURE

AOI Issue Date	09/12/2023
Submission Deadline for Full Applications	11/14/2023
DOE Share (80%)	$700,000
Cost Share (20%)	$175,000
Anticipated No. of Awards	3
Maximum Period of Performance	24 Months (Single Phase/ Single Budget Period)

Research Sought

A digital twin (DT) is a digital construct[31] that corresponds in all significant details to a physical system (a "physical twin"). Sensors provide data about the physical twin to controls and algorithms feeding both.[32] Digital twins may be used for a wide variety of applications within the context of sustainable hydrogen with carbon management systems, including (but not limited to): improving the performance of its physical counterpart by performing verification, prediction, and optimization; protecting information, preserving data integrity, and deploying mitigation strategies during cyberattacks; and investigating scenarios for design, re-design, and retrofit of components and systems. Additionally, as the United States and the world strive to eliminate carbon emissions, DTs can help with the development and integration of carbon capture technology to enable net-zero systems and help optimize flexible operations to accommodate increased participation of variable renewable power sources.

Gasification is one versatile feedstock- and product-flexible technology that can use a variety of low-cost and/or environmentally problematic feedstocks including waste coal, municipal solid waste (MSW), biomass, and waste plastics, to produce power, liquid fuels, chemicals and/or hydrogen.[33] Furthermore, use of renewable biomass while coupling the process to carbon capture and storage can potentially enable hydrogen production with net zero or even negative carbon emissions.

However, in the current or foreseeable market, large new gasification plants to produce hydrogen are unlikely to compete with large-scale hydrogen production by reforming of natural gas.[34] Smaller-scale modular gasification systems coupled to CCS, however, are desirable

[31]"What is a digital twin?," IBM, https://www.ibm.com/topics/what-is-a-digital-twin, accessed 5/15/2023
[32]"Digital Twins for Predictive Maintenance," MathWorks, https://www.mathworks.com/campaigns/offers/digital-twins-for-predictive-maintenance.html, accessed 5/15/2023
[33]United States Department of State and the United States Executive Office of the President [2021], "The Long Term Strategy of the United States—Pathways to Net Zero Greenhouse Gas Emissions by 2050," November 2021.
[34]Gangwal, S. (2022), "Coal and Combined Feedstock Gasification to Fuels, Chemicals and H2", Presented at the Gasification Technology Status and Pathways for Net-Zero Carbon Economy Workshop, November 2022.

because they can use site specific fuels/fuel blends, labor pool, and other resources, and in particular, more flexibly enable cycling the product between electricity and hydrogen to address local market needs and the penetration of renewables.

Research is sought under this AOI to develop digital twins for optimized performance, data integrity, and/or security of hydrogen production/utilization systems that feature integrated carbon capture under flexible operations. Target applications are limited to either 1) hydrogen production via gasification or 2) hydrogen/hydrogen-blend turbines. Desirable, but not required, is the application of artificial intelligence (AI)/ machine learning (ML) to support any portion of the DT and/or system processes.

Technical Elements that Must be Included in Applications

Proposals must provide the following:

- Specify the target application, the current state-of-the-art for DTs used for that application, and the specific way in which current R&D will contribute to the field.
- Clearly define the starting point for proposed R&D and the meaningful way a DT will be developed and/or leveraged for a specific purpose that contributes to stated goals.
- Systems under investigation must feature an integrated carbon capture process. This may be in the form of a point source capture technology, carbon dioxide removal, or some combination of carbon management technologies to achieve net-zero GHG operations.
- The DT must address dynamic grid connected power generation load profiles, representing flexible operations.
- Actual process signal data must be integrated into the DT along with other models as appropriate.
- The Applicant must develop methods to quantify the benefits of the DT technology (tighter controls for achievement of net-zero CO_2; decreased costs; etc.).

All applications must include a Community Benefits Plan (CBP), which includes: (1) a Diversity, Equity, Inclusion, and Accessibility (DEIA) section; (2) a completed Environmental Justice (EJ) Questionnaire; and (3) a completed Economic Revitalization and Job Creation (ERJC) Questionnaire for evaluation under Merit Review Criterion (MRC) 4. See **Appendices HH, FF, & GG** for guidance on preparing these documents.

Research Scope and Attributes that are Not of Interest

Applications with a system that does not include a carbon management subsystem towards achievement of net-zero GHG emissions will be considered non-responsive and will not be evaluated by DOE.

Anticipated Technology Readiness Level

Beginning of project: 2-3

End of project: 3-5

Success Metric(s)

Desired project outcomes include:

- At a minimum, projects will conduct a lab-scale demonstration of a DT running in parallel with a real system (TRL 3 or above) operating under flexible conditions
- Projects will develop a framework and/or methodology to quantify the benefits of DT

Technology Maturation Plan

A technology maturation plan (TMP) will be required as a deliverable before the end of the project.

Workforce Readiness Plan

A Workforce Readiness Plan will not be required as a deliverable in the SOPO for this AOI.

Questionnaires

- A preliminary "Environmental Justice Questionnaire" will be required with applications as part of the CBP and evaluated for this AOI. The preliminary version will later be updated in the final report. See **Appendix FF** for the Questionnaire.
- A preliminary "Economic Revitalization and Job Creation Questionnaire" will also be required with applications as part of the CBP and evaluated for this AOI. The preliminary version will later be updated in the final report. See **Appendix GG** for the Questionnaire.

APPENDIX V – PRODUCTS AND FEEDSTOCKS SPECIFICATIONS

A. Hydrogen and Carbon Dioxide

International directives have obligated hydrogen providers with the responsibility to prove that their hydrogen is of suitable quality for fuel cell vehicles, whether contaminants originate from hydrogen production, transportation, refueling stations, or maintenance operations[35]. Table R1 quantifies the U.S. DOE's recommended H_2 specifications for transportation fuel cell use[36]. This specification can be broadly applied to transportation hydrogen being distributed in the nascent hydrogen economy in the United States. Table R2 provides a recommended H_2 purity standard that would reasonably accommodate the integrity and operability considerations of hydrogen boilers and might be suitable as a standard for other end-use cases[37].

[35] "Probability of occurrence of ISO 14687-2 contaminants in hydrogen: Principles and examples from steam methane reforming and electrolysis (water and chlor-alkali) production processes model," Bacquart et al., *International journal of hydrogen energy* 43 (2018) 11872-11883.

[36] U.S. Department of Energy (DOE), 2016, "Specifications of Polymer Electrolyte Fuel Cells in Road Vehicles," Fuel Cell Technologies Office. Report to the Safety, Codes, and Standards Program. Report No. DOE/EE-1493.

[37] Hy4Heat (WP2) "Hydrogen Purity – Final Report," 2019, UK Department for Business, Energy & Industrial Strategy.

Table R1. Recommended H_2 specifications for transportation fuel cell use (DOE 2016)[21]

Characteristics (assay)	**Type I, Type II Grade D**
Hydrogen fuel index (minimum mole fraction)[a]	99.97%
Total non-hydrogen gases	300 µmol/mol
Maximum concentration of individual contaminants	
Water (H_2O)	5 µmol/mol
Total hydrocarbon [b] *(Methane basis)*	2 µmol/mol
Oxygen (O_2)	5 µmol/mol
Helium (He)	300 µmol/mol
Total Nitrogen (N_2) and Argon (Ar) [b]	100 µmol/mol
Carbon dioxide (CO_2)	2 µmol/mol
Carbon monoxide (CO)	0.2 µmol/mol
Total sulfur compounds [c] *(H_2S basis)*	0.004 µmol/mol
Formaldehyde (HCHO)	0.01 µmol/mol
Formic acid (HCOOH)	0.2 µmol/mol
Ammonia (NH_3)	0.1 µmol/mol
Total halogenated compounds [d] *(Halogenate ion basis)*	0.05 µmol/mol
Maximum particulates concentration	1 mg/kg

NOTE: *For the constituents that are additive, such as total hydrocarbons and total sulfur compounds, the sum of the constituents are to be less than or equal to the acceptable limit. The tolerances in the applicable gas testing method are to be the tolerance of the acceptable limit.*

[a] *The hydrogen fuel index is determined by subtracting the "total non-hydrogen gases" in this table, expressed in mole percent, from 100 mole percent.*

[b] *Total hydrocarbons include oxygenated organic species. Total hydrocarbons are measured on a carbon basis (µmolC/mol). Total hydrocarbons may exceed 2 µmol/mol due only to the presence of methane, in which case the summation of methane, nitrogen, and argon is not to exceed 100 ppm.*

[c] *As a minimum, include H_2S, COS, CS_2 and mercaptans, which are typically found in natural gas.*

[d] *Includes, for example, hydrogen bromide (HBr), hydrogen chloride (HCl), chlorine (Cl_2), and organic halides (R-X).*

Table R2. Recommended H_2 specifications for heating/boiler applications [22]

Content or Characteristic	Value	Rationale
Hydrogen (minimum mole fraction)	98 %	Hydrogen cost vs effects on boiler.
Carbon monoxide	20 ppm	Achievable production vs long term exposure.
Hydrogen sulfide content	≤ 5 mg m^{-3} 3.5 ppm	Similar to values established for natural gas (assuming repurposed pipeline network).
Total sulfur content (including H_2S)	≤ 50 mg m^{-3} 35 ppm	
Oxygen content	≤ 0.2 %	
Hydrocarbon dewpoint	-2 °C	Avoids liquid drop-out.
Water dewpoint	-10 °C	
Sum of methane, carbon dioxide, and total hydrocarbons	≤ 1 %	No detrimental effects to boiler, this limit is to reduce carbon content of the exhaust.
Sum of argon, nitrogen, and helium	≤ 2 %	To avoid transporting inert gases (in agreement with ISO/FDIS 14687) and limit the impact on Wobbe Number (see below).
Wobbe Number range	42 – 46 MJ m^{-3}	Wobbe Number is calculated at UK metric standard conditions of 15 °C and 101.325 kPa.
Other impurities	No solid, liquid, or gaseous material that might interfere with the integrity or operation of pipes or any gas appliance.	

Table R3. Specification of Carbon Dioxide By-product Composition (NETL, Jan 2019) [38]

Component	Unit*	Carbon Steel Pipeline	Enhanced Oil Recovery	Saline Reservoir Sequestration
CO_2	vol% (min)	95	95	95
H_2O	ppm_v	500	500	500
N_2	vol%	4	1	4
O_2	vol%	0.001	0.001	0.001
Ar	vol%	4	1	4
CH_4	vol%	4	1	4
H_2	vol%	4	1	4
CO	ppm_v	35	35	35
H_2S	vol%	0.01	0.01	0.01
SO_2	ppm_v	100	100	100
NO_x	ppm_v	100	100	100
NH_3	ppm_v	50	50	50
COS	ppm_v	trace	5	trace
C_2H_6	vol%	1	1	1
C_3+	vol%	<1	<1	<1
Particulate	ppm_v	1	1	1
HCN	ppm_v	trace	trace	trace
Glycol	ppb_v	46	46	46

** Maximum permissible unless otherwise noted*

[38] "CO_2 Impurity Design Parameters—Quality Guidelines for Energy System Studies," Final Report, NETL, January 2019.

B. Waste Plastics

*Table R4. Specification of Mixed Waste Plastics (*ARL-TR-7394, 2015*)*[39]

Component	Percentage	Heat Content (dry basis) (Btu/lb)
#1 Polyethylene terephthalate (PET)	40.0	10,250
#2 High density polyethylene (HDPE)	18.0	19,000
#3 Polyvinyl chloride (PVC)	5.9	8,250
#4 Low density polyethylene (LDPE)	18.0	12,050
#5 Polypropylene (PP)	2.0	19,000
#6 Polystyrene (PS)	12.0	17,800
#7 Other*	4.1	13,332
Average Mixed Waste Plastic	100	13,240

**Polycarbonate, acrylic, nylon, bioplastics, composites, etc.; but assumed to be polycarbonate on heating basis*

C. Coals

Table R5. Specification of Montana Rosebud PRB Sub-Bituminous Coal (NETL, 2014a)[40]

Property	As Received	Dry Basis	As Fed
Proximate Analysis			
Moisture (%)	25.77	0.00	18.00
Ash (%)	8.1	9 11.04	9.05
Volatile Matter (%)	30.34	40.87	33.51
Fixed Carbon (%)	35.70	48.09	39.43
Ultimate Analysis			
C (%)	50.07	67.45	55.31
H (%)	3.38	4.56	3.74
O (%)	11.14	15.01	12.31
N (%)	0.71	0.96	0.79
S (%)	0.73	0.98	0.80
Cl (%)	0.01	0.01	0.01
Ash (%)	8.19	11.03	9.04
Moisture (%)	25.77	0.00	18.00
Heating Value			
HHV (Btu/lb)	8,564	11,516	9,443
LHV (Btu/lb)	8,252	11,096	9,079

[39] "Test Standards for Contingency Base Waste-to-Energy Technologies," Margolin et al, U.S. Army Research Laboratory, ARL-TR-7394, August 2015.

[40] (NETL 2014a). Comprehensive Analysis of Coal and Biomass Conversion to Jet Fuel: Oxygen Blown, Transport Reactor Integrated Gasifier (TRIG) and Fischer-Tropsch (F-T) Catalyst Configurations," (DOE/NETL-2012/1563), Pittsburgh, PA: National Energy Technology Laboratory.

Table R6. Specification of Illinois No. 6 Bituminous Coal (NETL, 2014b)[41]

Property	As Received	Dry Basis	As Fed
Proximate Analysis			
Moisture (%)	11.12	0.00	6.00
Ash (%)	9.70	10.91	10.26
Volatile Matter (%)	34.99	39.37	37.00
Fixed Carbon (%)	44.19	49.72	46.74
Ultimate Analysis			
C (%)	63.75	71.72	67.42
H (%)	4.50	5.06	4.76
O (%)	6.89	7.75	7.29
N (%)	1.25	1.41	1.33
S (%)	2.51	2.82	2.65
Cl (%)	0.29	0.33	0.31
Ash (%)	9.70	10.91	10.26
Moisture (%)	25.77	0.00	18.00
Heating Value			
HHV (Btu/lb)	11,666	13,125	12,337
LHV (Btu/lb)	11,252	12,712	11,899

[41] (NETL 2014b). "Cost and Performance Baseline for Fossil Energy Plants Volume 4: Coal-to-Liquids via Fischer-Tropsch Synthesis," (DOE/NETL-2011/1477), Pittsburgh, PA: National Energy Technology Laboratory.

Table R7. Specification of North Dakota Lignite (NETL, 2012)[42]

Property	As Received	Dry Basis
Proximate Analysis		
Moisture (%)	36.08	0.00
Ash (%)	26.52	41.48
Volatile Matter (%)	9.86	15.43
Fixed Carbon (%)	27.54	43.09
Ultimate Analysis		
C (%)	39.55	61.88
H (%)	2.74	4.29
O (%)	10.51	16.44
N (%)	0.63	0.98
S (%)	0.63	0.98
Cl (%)	0.00	0.00
Ash (%)	9.86	15.43
Moisture (%)	36.08	0.00
Heating Value		
HHV (Btu/lb)	6,617	10,427
LHV (Btu/lb)	6,364	10,032

[42] (NETL 2012). "Quality Guidelines for Energy Systems Studies: Detailed Coal Specifications," (DOE/NETL-401/02111), Pittsburgh, PA: National Energy Technology Laboratory.

D. Biomass

The specifications for biomass given include three common types consisting of woody biomass (torrefied and non-torrefied) and switchgrass. However, there are other important biomass types (corn stover, bagasse, etc.) that may need to be considered in waste plastic/biomass/coal to H_2 process scenarios. Additionally, it is possible that certain waste fuels might be considered as similar to biomass in functionality (e.g., sludge, black liquor). EERE's Biomass Energy Databook may be consulted for specifications of certain of these additional biomass materials. Appendices A and B of the 4th edition of the Databook contain some of that information in the form of heat content ranges for biomass fuels, and useful characteristics including ash content, sulfur, and potassium content, etc.[43].

Table R8. Specification of Southern Pine Biomass (non-Torrefied) (NETL, 2014a)[25]

Property	As Received	Dry Basis	As Fed
Ultimate Analysis			
C (%)	30.55	53.88	44.18
H (%)	3.02	5.33	4.37
O (%)	22.25	39.25	32.19
N (%)	0.23	0.41	0.34
S (%)	0.02	0.04	0.03
Cl (%)	0	0	0
Ash (%)	0.62	1.09	0.89
Moisture (%)	43.3	0	18.00
Heating Value			
HHV (Btu/lb)	4,922	8,681	7,118
LHV (Btu/lb)	4,178	8,175	6,514

[43] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE), "Biomass Energy Data Book: Edition 4," ORNL/TM-2011/446, September 2011

Table R9. Specification of Torrefied Southern Pine Biomass (NETL, 2014a)[25]

Property	As Received	Dry Basis	As Fed
Ultimate Analysis			
C (%)	59.89	63.52	59.89
H (%)	5.11	5.42	5.11
O (%)	28.36	30.08	28.36
N (%)	0.41	0.44	0.41
S (%)	0	0	0
Cl (%)	0	0	0
Ash (%)	0.51	0.54	0.51
Moisture (%)	5.72	0	5.72
Heating Value			
HHV (Btu/lb)	9,749	10,340	9,749
LHV (Btu/lb)	9,203	9,825	9,203

Table R10. Specification of Switchgrass (NETL, 2014b)[26]

Property	As Received	Dry Basis	As Fed
Ultimate Analysis			
C (%)	39.92	46.97	44.15
H (%)	4.86	5.72	5.37
O (%)	34.16	40.19	37.78
N (%)	0.73	0.86	0.80
S (%)	0.08	0.09	0.08
Cl (%)	0.00	0.00	0.00
Ash (%)	5.26	6.19	5.82
Moisture (%)	15.00	0.00	6.00
Heating Value			
HHV (Btu/lb)	6,851	8,060	7,576
LHV (Btu/lb)	6,405	7,536	7,084

APPENDIX W – 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.

Example – 20% cost share
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 a 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 Sub-recipient(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 Sub-recipient(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 Sub-recipients. Non-federal sources include any source not originally derived from federal funds. Cost sharing commitment letters from Sub-recipients 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 X – WAIVER REQUESTS: FOREIGN ENTITY PARTICIPATION AS THE PRIME RECIPIENT AND PERFORMANCE OF WORK IN THE UNITED STATES

i. Waiver for Foreign Entity Participation as the Prime Recipient

As set forth in Section III, 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 require additional information before considering the waiver request.

The Applicant does not have the right to appeal DOE's decision concerning a waiver request.

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

As set forth in Section IV, 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 Sub-recipients) 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).

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 Y – STATEMENT OF PROJECT OBJECTIVES TEMPLATE

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/sub-tasks, 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).

Task 1.0 - Project Management and Planning (REQUIRED; APPLICANT INSERT THIS TASK)

Sub-task 1.1 – Project Management Plan (REQUIRED; APPLICANT INSERT THE LANGUAGE PROVIDED BELOW IN QUOTES. SEE **APPENDIX Z** 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."

Sub-task 1.2 – Technology Maturation Plan (REQUIRED; APPLICANT INSERT THE LANGUAGE PROVIDED BELOW IN QUOTES. REFERENCE **APPENDIX DD** FOR FORMAT.)

"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 TMP should be submitted in accordance with the Deliverables table in Section D."

Sub-task 1.3 – Community Benefits Plan (REQUIRED; APPLICANT INSERT THE LANGUAGE PROVIDED BELOW IN QUOTES. REFERENCE **APPENDICES HH, FF, & GG**.)

"The Recipient will manage and direct Community Benefits related activities under the project in accordance with a Community Benefits Plan, initially submitted as part of the award application package, and updated in collaboration with the DOE Project Officer within 90 days of award. The plan will include a Diversity, Equity, Inclusion, and Accessibility (DEIA) section with clearly defined specific, measurable, achievable, relevant, and time-bound (SMART) milestones that will be used in guiding planned Community Benefits efforts. The Recipient will coordinate activities in order to effectively accomplish the work identified by the CBP and its associated milestones. The Recipient will ensure that the CBP, as well as the costs, implementation efforts, key decisions, and results of the efforts are appropriately documented throughout the project period.

The Recipient will address their progress towards meeting the objectives and milestones set forth in their CBP on an annual basis as part of their annual briefing, throughout the project at any point at which substantial change to the document is necessitated as part of project efforts, and/or as requested by the NETL Project Manager.

The preliminary Environmental Justice Questionnaire and Economic Revitalization and Job Creation Questionnaire submitted in the application package as part of the CBP will be updated at the completion of the project and included as an appendix to the project Final Report.

The results and status of Community Benefits-related activities will be provided as an element of performance during project reviews, in quarterly progress reports, as part of the project final report, and as otherwise requested by the DOE Project Officer or their designee."

APPLICANT continue with tasks/sub-tasks as necessary. If the project is structured in Phases, clearly delineate which tasks/sub-tasks are in each Phase.

Task 2.0 - (Title)
Task descriptions should include a concise description of the work to be conducted for each task. If the task includes sub-tasks, provide a general description of how each sub-task is related to the overall scope of the task.

Sub-task 2.1 - (Title)
Sub-task descriptions should include a concise description of the work to be conducted for each sub-task.

Sub-task 2.2 - (Title)

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 / Sub-task 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)	Due Date differs by AOI. Insert language below for the corresponding AOI. **AOI 18 ONLY:** Updates to the initial TMP submitted with the application shall be submitted, as needed, throughout the project period of performance. **AOI 19 ONLY:** The initial TMP is due 90 days after award. Updates to the TMP shall be submitted, as needed, throughout the project period of performance. **AOI 20 ONLY:** The TMP shall be submitted before the end of the period of performance.

1.3	Community Benefits Plan	Initial update of CBP due 90 days after project start date. Annual progress updates due as part of annual briefings, as necessitated by substantial change to project efforts, and/or as requested by the NETL Project Manager.
1.3	Environmental Justice Questionnaire	Updated Environmental Justice Questionnaire to be submitted as an attachment to the final report.
1.3	Economic Revitalization and Job Creation Questionnaire	Updated Economic Revitalization and Job Creation Questionnaire to be submitted as an attachment to the final report.

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/Sub-task 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 Z – PROJECT MANAGEMENT PLAN TEMPLATE

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/Sub-task 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 Sub-task 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/ Sub-task	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.

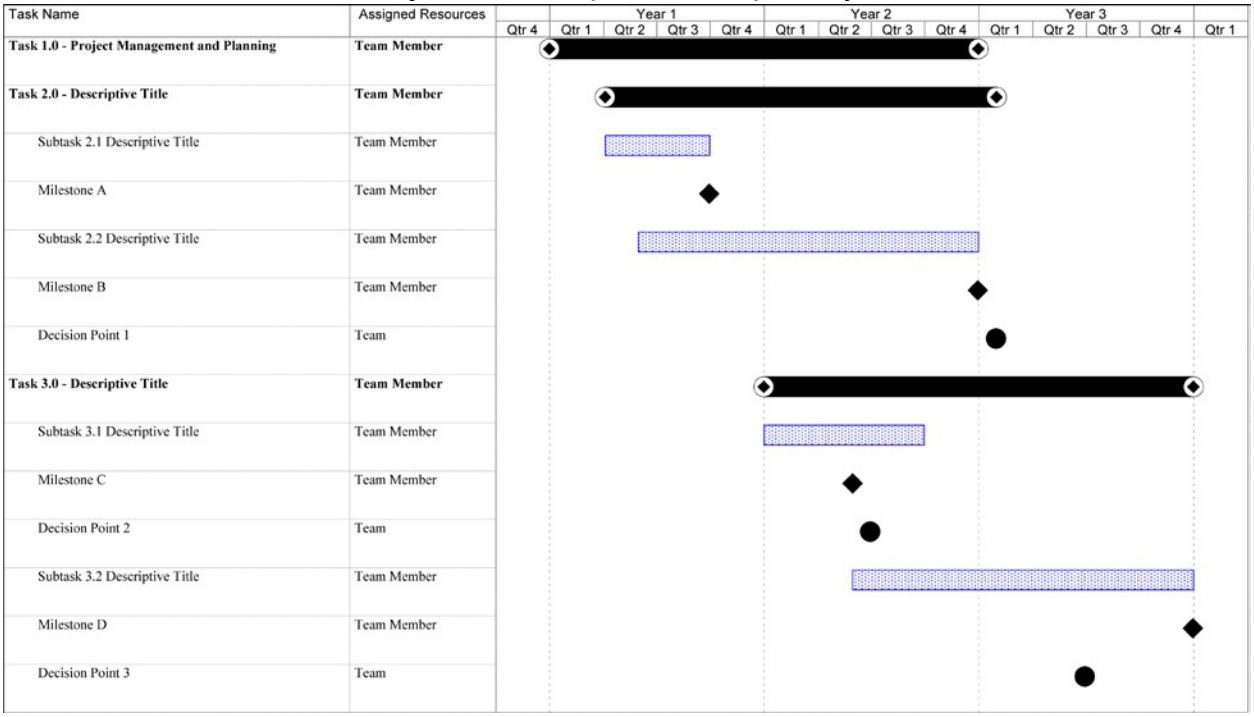
Spend Plan by Fiscal Year Format

	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										
Sub-recipient A, if proposed										
Sub-recipient 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 sub-task, 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 D).

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 AA - 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 BB – Guidance for Project Teams on Diversity, Equity, Inclusion, and Accessibility Plans

1. Background and FAQ

The Diversity, Equity, Inclusion, and Accessibility (DEIA) Plan describes the actions your project team will take, if selected for award, to foster a welcoming and inclusive environment, support people from groups underrepresented in science, technology, engineering, and math (STEM) and/or applicable workforces, advance equity, and encourage the inclusion of individuals from these groups in future phases of the project.

Diversity includes a broad spectrum of characteristics including, but not limited to, race, color, ethnicity, national origin, age, religion, culture, language, disability, sexual orientation, gender identity, socioeconomic status, family structure, geographic differences, diversity of thought, technical expertise, and life experiences.
Equity means the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment.
Inclusion means the recognition, appreciation, and use of the talents and skills of employees of all backgrounds.
Accessibility means the design, construction, development, and maintenance of facilities, information and communication technology, programs, and services so that all people, including people with disabilities, can fully and independently use them. Accessibility includes the provision of accommodations and modifications to ensure equal access to employment and participation in activities for people with disabilities, the reduction or elimination of physical and attitudinal barriers to equitable opportunities, a commitment to ensuring that people with disabilities can independently access every outward-facing and internal activity or electronic space, and the pursuit of best practices such as universal design.

Creating a DEIA plan involves four basic steps:

(1) Formulate **why** you are creating a DEIA plan for this project, beyond funding requirements. Common reasons for organizations to implement DEIA plans include: to cultivate a workplace culture that will attract and retain top talent, to align practices with the values members hold, to better communicate with clients and other stakeholders, and to act on research that a more diverse organization or project will improve creativity and productivity.[44] Clarity on this vision for DEIA in your project will help to build buy-in for a plan that is implemented.

[44] (Science benefits from diversity (nature.com); [PDF] The preeminence of ethnic diversity in scientific collaboration | Semantic Scholar

(2) **Assess** the current state of diversity, equity, inclusion, and accessibility in your organization and within your project. There are some guiding questions below that can help. This will be an initial assessment; if there are knowledge gaps, identify internal analysis needs and itemize those needs in the plan.

(3) Develop **goals and desired outcomes**. What does success in achieving these goals look like? How will it be measured?

(4) Develop **implementation strategies** to reach those outcomes. This includes specifying roles and responsibilities, defining required resources, and developing a timeline for executing the strategies.

How long should the plan be? What level of detail is required?
The plan should be a maximum of five pages. We recommend that the plan be focused on specific, measurable outcomes and implementation strategies. This table summarizes the deliverables in the plan.

Element	Description	Suggested Length
1. Background	Short description of context of DEIA in the project team and organization, and any previous efforts to address DEIA	1-1.5 pages
2. Milestones and Timeline	Outcomes and implementation strategies, including SMART milestones and a timeline for execution	2-3 pages
3. Resource Summary	Description of resources needed to support the plan	1-1.5 pages

How much of the written plan should be devoted to detailing each of these steps?
A general rule of thumb is that less than half of the plan should be devoted to assessment; it is important to not just measure the status quo but spend time articulating outcomes and implementation strategies.

We already have a DEIA policy; how does it need to be modified for this FOA?
It really depends on what your DEIA policy covers and whether it has enough specific, measurable actions to be considered a plan. A lot of organizations have DEIA *statements.* These often affirm an organization's values and commitment. DEIA *policies* often involve procedures for what to do when encountering bias in the workforce, or programs in place. These are actually different than DEIA *plans*, which involve measurable outcomes and implementation strategies. In many cases, the plan spells out what will be done to implement the policy. In other words, chances are it would not be adequate to submit your organization's DEIA policy, though there are probably things in it you could point to in terms of your initial assessment.

A lot of DEIA topics sound like what HR deals with, but we as Applicants don't control what HR does — so how are we supposed to write about changing it?
This is totally understandable; when it comes to hiring, retention, etc., focus on project hires and other decisions, like collaboration or contracting, that you might have control over. It's also fruitful to focus on what you can do to foster an inclusive culture within your project. People often mistake DEIA for a HR matter; the aim here is to weave it throughout the whole organization and project. While you don't want to put things in the plan that you don't have control over, you can identify ways you might liaise with HR to suggest new practices.

Who can help us create a DEIA plan?
Many organizations, like universities or larger companies, have dedicated resources for DEIA work. Professional societies often do as well. Further resources are included at the end of this document.

2. Process for creating the plan

Formulating a vision for DEIA in your project
This step focuses on discussing why you are creating a DEIA plan. The internal process for formulating your vision will obviously vary by institution, and if resources are available — e.g., if your organization has a DEI office — it may be useful to have an external facilitator work with you on a discussion of DEI vision. Or it may just involve a team meeting. The key point is that team members are on the same page about why you are putting together a DEIA plan, as well as how it fits into existing efforts. It would be appropriate to include in the plan a few sentences on the outputs of that conversation (e.g., a DEI vision statement). Some advice for vision and mission statements including DEIA can be found at:
http://www.nonprofitinclusiveness.org/building-inclusiveness-your-mission-and-values.

Doing an initial assessment
In your plan, you should summarize the results of an initial assessment of DEIA in your project. There may be aspects where you lack data, and in this case, gathering that data and analyzing it should be included in your plan (including specifying what data sources you will need; how to gather new data if you need it; who will gather the data and analyze it; how long it will take; etc.). You will probably draw on both internal and external data (e.g., for benchmarking), as well as both **qualitative and quantitative data**.

Guiding questions for an initial assessment could involve the following. **We do not expect plans to answer all these questions; we list them here as a resource for you to draw from as you design the initial assessment.** Answering these questions can help you think about outcomes and implementation strategies.

Assessing DEIA training and culture in your organization

- Does your project or organization have an existing DEIA mission statement and philosophy?

- Do project leaders support this DEIA mission, especially as it informs creating a diverse and inclusive work environment? Provide examples of how.
- What percentage of your organizational resources, in terms of staff, staff time, funding, etc., goes to DEIA activities?
- Is there a reporting process that tracks DEIA milestones and metrics in your organization? Does the reporting process involve transparent, third-party reporting systems, and incorporate employee feedback?
- What existing employment, salary, retention, and promotion data is tracked about your organization; is it disaggregated by race, gender, and other variables? Is this data shared with employees and/or made public?
- What are the DEIA training requirements and learning opportunities for employees? What mechanisms are used to measure the effectiveness of these training activities?
- How are participation and outcomes tracked, measured, and shared? Are there DEIA elements in staff performance appraisals, and clear guidance and examples of how employees will be evaluated and what successful performance looks like?

For the above:

- Are these policies and practices well-known among the employees — what percent of employees are familiar with them?
- Are these policies and practices clear and effective?

Assessing hiring, including, collaborating with, and contracting with persons from underrepresented groups

Basic analysis:

- How many people are in your organization and what is the breakdown between management and staff?
- What percent of people employed in your organization are from underrepresented groups?
- What percent of management is from under-represented groups?
- What percent of contracts are with minority, women, or veteran-owned businesses?
- What percent of collaborators (project partners, research collaborators, co-investigators, sub-contractors) are from under-represented groups? From minority-serving institutions (MSIs)? How are collaborations typically formed?
- How are current employment and diversity statistics benchmarked against appropriate comparison populations, such as existing employment data for specific STEM fields across the scientific community, not just the region, and existing graduation rates in specific fields, using, for example, the data available through the National Science Foundation's (NSF) National Center for Science and Engineering Statistics, and NSF Science & Engineering Indicators, and scientific professional societies?

Recruitment:

- What percent of job Applicants are from under-represented groups? What percent of hires are from under-represented groups?
- How diverse are your workforce recruiting networks (e.g., outreach programs and job

groups)?

- What efforts are taken to remove bias from job description language and developed objective hiring criteria? (Examples could include using gender-neutral pronouns and job titles, scanning for gender-coding or other phrases that signal unconscious bias towards age, race, or culture, evaluating language for being welcoming to Applicants with disabilities.)
- What training is offered to address implicit bias and ensure effective interviewing? Do you conduct anonymous resume screening, e.g., without candidate personally identifying information?

Retention and promotion:

- Are candidates assessed on their aptitude for supporting DEIA goals and an inclusive workplace culture, using standardized behavioral interview questions?
- How robust and transparent are your pay equity processes and are these grounded in statistical analysis with annual reviews? Are there formal remediation protocols?
- What employee benefits, policies, resources, and initiatives exist to improve well-being and address the needs of employees across career stages and personal family circumstances (e.g., family support services/childcare, alternative and flexible work schedules, etc.?)
- What strategies are in place to retain workers from underrepresented groups?
- Are promotion strategies tracked with an eye towards equity? Are voluntary and involuntary separations tracked with disaggregated data to examine trends?
- Are there mentorship opportunities and programs? If so, are they currently utilized equally by individuals from different identity groups?

Assessing knowledge sharing

Note: There may be parts of this section of the assessment that overlap with work in Justice40 and Engagement Plans – this is a good time to cross-reference.

- How diverse is your target audience when disseminating results? (e.g., do you prioritize MSIs, underserved communities, or organizations working with underserved communities) when sharing details and research outcomes of your work?
- How transparent and accessible is the information you share? Do you publicly disseminate the information and through what channels?
- Is data presented in meaningful ways for the purposes of community engagement and interpretation?
- Could the communication channels and language be rendered more accessible? Are there different forms of communication that need to be employed, e.g., for communities with different levels of digital access? What about language accessibility for speakers of other languages?
- Is the process of disseminating results empowering to those communities involved? In other words, are communities in a position to use the knowledge to pursue their priorities? If not, is there anything you could do to facilitate this?

Moving from goals to outcomes to implementation strategies

A goal is an aspiration, while an outcome is what it looks like when your goal is achieved. The implementation strategy spells out what needs to happen to reach that outcome, when it will happen, and who will do it.

Example 1: Bench-stage example of goal → outcome → implementation strategy

You lead a research group and are applying for funding to test a bench-scale carbon dioxide capture process. You analyze your past deliverables and note they have been exclusively reports to your funders or highly specialized peer-reviewed journal articles.

Perhaps you develop the **goal** of disseminating your research to a more diverse audience.

You may set your **outcome** as developing one relationship with a minority-serving institution (MSI) near where you work within the next year and sharing your results and expertise with them.

Your **implementation strategy** may involve things like contacting a specified number of departments or programs within the nearest MSIs to see if they would be interested in a research talk, or if they'd be interested in you sponsoring a research visit to your lab for their students to learn about your work and careers in your field.

Example 2: Bench-stage example of goal → outcome → implementation strategy

You lead a research group and your recent work identified next steps should include a collaborative project with experts in areas outside of your university. You have also made a personal commitment to work towards advancing equity and justice and have recently been increasing your efforts to integrate these values into your academic work.

Your **why(s)** might include the need to initiate a collaborative research project outside of your institution, and also your commitment to take action to meaningfully advance equity and justice in your research.

Your **assessment** could involve learning about and identifying minority-serving institutions with expertise in relevant research areas. You might also assess if there are any minority business enterprises, minority owned businesses, woman owned businesses, and veteran owned businesses to solicit as vendors and sub-contractors for bids on supplies, services, and equipment that will be required for this project.

Perhaps you develop the **goal** of increasing collaborative research with groups or individuals underrepresented in your STEM field.

You may set your **outcome** as developing one or more relationships with relevant research groups at minority-serving institution (MSI) and securing at least 1 grant to fund a joint research project with an MSI within 1 academic year.

Your **implementation strategy** may involve things like contacting a specified number of departments or programs at the relevant MSIs to see if they would be interested in a collaborative research project; after identifying interested partners(s), scoping out research roles, responsibilities, and funding in a way that would benefit groups equitably; and jointly applying to 2 upcoming grant opportunities.

Below is a list of actions that can serve as examples of ways the project could incorporate diversity, equity, and inclusion elements. These examples should not be considered either exhaustive or prescriptive. Applicants may include appropriate actions not covered by these examples and should include a comprehensive set of specific DEIA actions anticipated in connection with the project.

A good DEIA plan will include both **outcomes** and **implementation strategies** in one or all of these three areas. Please note there may be important DEIA activities that do not fit into these three topical areas.

Below are some examples of goals that may be identified through your initial assessment.

1) **Organizational and cultural change: Create or contribute to existing diversity, equity, and inclusion programs at your own or nearby organizations**
    - Enhance or collaborate with existing diversity, equity, and inclusion programs at your home organization and/or nearby organizations
    - Implement evidence-based, diversity-focused education programs (such as implicit bias training for staff) in your organization
    - Dedicate time and resources for team members to engage in DEI training, networking, and learning opportunities externally
    - Institute or improve reporting process for tracking DEIA milestones and metrics in the project
2) **Including, collaborating with, and contracting with persons from underrepresented groups**

For research / early technological readiness level (TRL) projects:

- Include persons from groups underrepresented in STEM as PI, co-PI, and/or other senior personnel
- Include persons from groups underrepresented in STEM as student researchers or post-doctoral researchers
- Include faculty or students from MSIs as PI/co-PI, senior personnel, and/or student researchers, as applicable
- Collaborate with students, researchers, and staff in MSIs
- Identify minority business enterprises, minority owned businesses, woman owned businesses, and veteran owned businesses to solicit as vendors and sub-contractors for bids on supplies, services, and equipment

For demonstration / mid-to-late TRL projects:

- Identify minority business enterprises, minority owned businesses, woman owned businesses, and veteran owned businesses to solicit as vendors and sub-contractors for bids on supplies, services, and equipment
- Identify diversity workforce training programs hosted by the proposed project and/or nearby organizations to foster improved access to jobs for members of the community, including individuals under-represented in relevant industries and those facing barriers to employment, such as those with disabilities
- Support ***quality pre-apprenticeship*** programs in the local community to improve access

to career-track training and jobs for underrepresented workers, including returning citizens. Who will you partner with to ensure successful outcomes?

Plans can include information and commitments for *hiring, retention, contracting and collaboration, and workforce development*.

3) Education and outreach in your work: Consider DEIA when sharing knowledge or results

- Disseminate results of research and development in MSIs or other appropriate institutions serving underserved communities.
- Make data available and accessible to communities that may be interested.
- Work with community groups to figure out how results or insights from your work could be useful for community priorities.
- Create educational opportunities for schools or other educational institutions in underserved communities where your project team could share their expertise on topics that the communities are interested in.

SMART milestones are a tool to move from goals to outcomes to implementation

The plan should include at least one Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) milestone nominally per year, supported by metrics to measure the success of the proposed DEIA Plan actions.

In project management within DOE, SMART milestones have historically related to technical achievements. But more generally within management studies, the formula has been adapted to a range of goals.

Some tips for SMART milestones:

- For "Specific," make your goals narrow and concrete—this will enable the measurability of the goal.
- For "Measurable," identify what data or evidence you can use to assess whether you are making progress towards or achieving your goal.
- In terms of "Achievable," knowing your benchmarks as well as where other companies or organizations are at can help you calibrate what is achievable. This should also take into account the time and resources you have available to implement this goal.
- In terms of "Relevance," refer back to Step 1 — why your organization is pursuing DEIA — to tie in the milestone to things that are relevant for your organization.
- With "Time-bound," consider setting interim milestones on the way to a larger goal.

Brookhaven National Labs has some advice on SMART goals related to DEIA at https://www.bnl.gov/training/docs/pdf/ID-Goals-Toolkit.pdf.

3. Structure of the plan / Deliverables

The output of this planning work will be summarized in a document that you submit that is up to 5 pages long. This document should be sure to cover:

1. **Background**: Context and findings from initial assessment
    - This is recommended to be short, and no more than half the document

- It can describe how the project team's DEI work fits in with the larger organization's strategy
- It can also cover key data points and include charts or graphs as useful

2. **Milestones and timelines**: Outcomes and implementation strategies, including SMART milestones and a timeline for execution.
    - This could be presented in table or graphical form, or as narrative
    - The DEIA Plan schedule should:
        - Propose when the team will begin implementing this plan, which will be no later than 90 days into the project.
        - Define the timeline on the same schedule as the Project Management Plan. It is expected that pivotal points in the DEIA plan's schedule are also included in the Project's SOPO.
        - Include a description of future DEIA activities for future work either under DOE awards or the lifecycle of the storage facility.
3. **Resource summary**: A description of the resources required to support implementing the plan. Include information about:
    - Number of staff, their time on project, and experience, e.g., educational qualifications, people trained in DEIA, facilitation, and/or social science.
    - Contracting or partnering with organizations with relevant expertise.
    - Facilities, equipment, and capabilities: Physical buildings and meeting spaces, specialized equipment for use in research, scientific, and DEIA work, and/or the abilities staff, facilities, and equipment enable for the project.
    - Budget (both federal and/or cost share aligned with activities in the plan).
    - Risks to achieving certain goals, such as lack of organizational support, funding, expertise, etc.
    - A discussion of how any identified barriers can be overcome / how the required resources will be obtained.

How exactly you structure this material is up to you — we also recommend organizing the plan in a way that makes sense for the people in your project / organization and will be read by them. Common sections might include Background, a Vision / Mission / Goals section that sets out what you hope to achieve (but keep this relatively short), Outcomes, and Implementation Strategies, including roles and timelines, etc. The main thing is that it contains the three elements mentioned above.

4. Further questions

How do we know if our DEIA plan is well developed?

An inadequate DEIA plan might include a few vague commitments to values without specific, actionable items.

A good DEIA plan will include SMART milestones, roles, and responsibilities for who is executing the plan, and timelines. This includes identifying targets by which success can be measured.

A good DEIA plan is also one your organization will act upon to implement. This means that there should be good prospects for buy-in among all the people who have roles and responsibilities for enacting the plan; evidence of having begun or mapped out those conversations can be useful.

How do we avoid creating additional burdens for members of underrepresented groups?
There is a history of well-intentioned but rushed and not-fully-considered DEIA work that creates additional harms or burdens for underrepresented groups. Often people from underrepresented groups are asked to take on this work in a volunteer capacity or are informally consulted on various DEIA topics without compensation, sometimes by multiple employees or teams who think their ask is light and don't realize how it all adds up. It is critical to analyze who is being asked to carry the load, how other work responsibilities are shifted to accommodate it, and how compensation for this work is done. Recognition for DEIA work should not just be financial; it comes at the expense of other activities and should be considered in review and promotion.

Resources
National Labs Diversity Goals: https://nationallabs.org/staff/diversity/
Promising Practices: Summary-of-SC-DOE-Laboratory-DEIA-Promising-Practices-2020---vpublic.pdf (osti.gov)
Guide to Minority Serving Institutions: https://diversitytoolkit.com/minority-serving-institutions/
DOE Energy Workforce Division: https://www.energy.gov/diversity/energy-workforce-division
Diversity, Equity and Inclusions definitions: Federal Register :: Diversity, Equity, Inclusion, and Accessibility in the Federal Workforce
Common Mistakes When Creating a DEIA Policy: Avoid these 8 common mistakes when creating a D&I policy (fastcompany.com)

APPENDIX CC – TECHNOLOGY READINESS LEVELS

The following is a description of the DOE Technology Readiness Levels.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
System Operations	TRL 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	TRL 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.
	TRL 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.
Technology Demonstration	TRL 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.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
Technology Development	TRL 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	TRL 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.
Research to Prove Feasibility	TRL 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.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
Basic Technology Research	TRL 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.
	TRL 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.

Source: U.S. Department of Energy, "Technology Readiness Assessment Guide". Office of Management. 2011.

APPENDIX DD – TECHNOLOGY MATURATION PLAN INSTRUCTIONS AND TEMPLATE

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.

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 template below 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.

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

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[45] components have been 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.

[45]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.

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"><u>Minimum Simultaneous Requirements</u> 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 <u>applies</u> the fundamental science is initiated in conceptual paper studies but experiments on the <u>applied</u> technology have not begun.</td><td>NA</td></tr>
<tr><td>2</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="3">Lab</td><td>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><td rowspan="2">High (nearly a prototype)</td><td rowspan="3">Relevant
(regulated expected conditions)</td></tr>
<tr><td>5</td><td>Laboratory scale, similar system* validation in relevant environment</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 CO2 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 EE – WORKFORCE READINESS PLAN TEMPLATE

This is a suggested format. If it makes sense for the Recipient to present the information in a different format, it may do so provided all content is covered.

Recipient Name:
PI Name:
Award Number:
Project Title:
Technology:

What are the occupations and necessary skills, certificates, certifications, or other educational attainment involved in the occupations related to this technology/activity?
Examples include applicable skills, apprenticeships, certificates, certifications, academic training, or other programs available through in-house training or in coordination with education institutions such as community colleges, technical schools, universities, unions, or other professional associations.

What is the availability and accessibility of training programs and current and projected future demand for these occupations?
Describe any training required to prepare the workforce needed to commercialize/deploy the technology and if there is availability of training and educational programs to fill current or projected activity / commercialization need as well as any projected future demand for training.

Does this activity have any ongoing or planned collaborations with education and training providers?
Describe how the Recipient plans to access any necessary training for its workforce, through coordination with educational institutions such as community colleges, technical schools, and universities, company-led, in-house training, union training, etc. Please identify any institutions with which working relationships exist.

Is there a need for the creation of a new workforce training program for this specific technology being developed to meet demand or to teach new skills necessary for emerging technologies?
This may include the creation of new apprenticeship, certificate, certifications, or other related training programs with educational training providers, like community colleges or universities or others. Ex. New welding techniques, skills necessary for advanced materials, increased demand for IT and coding skills, etc.

APPENDIX FF – ENVIRONMENTAL JUSTICE QUESTIONNAIRE

1. How does the developmental technology rely on limited resources such as natural gas, coal, 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. What are the environmental benefits associated with this project and/or the developmental technology? How will these benefits impact disadvantaged communities (Justice40 Initiative | Department of Energy), Tribes/Alaska Native Corporations (ANCs), fossil energy communities, and/or other communities in the project area?

3. How does the developmental technology remediate legacy environmental impacts of the energy industry, including environmental impacts associated with the use of coal or natural gas?

4. To what extent does the developmental technology provide ancillary environmental benefits, such as reductions in NOx and SOx emissions, particulate matter, or hazardous pollutants?

5. If fossil feedstocks are used, where will these resources be extracted and what are the associated near-term and legacy environmental impacts of the extraction, including methane leakage?

6. If fossil feedstock derived wastes are being remediated, what is the relationship between the amount of coal wastes used versus the amount of product formed?

7. What is the project's waste management strategy and what are the anticipated impacts of residual waste on local residents?

8. 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)?

9. 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?

10. Does the Applicant plan to share data with state and local governments? Communities in or adjacent to potential project areas? Disadvantaged communities? Tribal communities or ANCs?

APPENDIX GG – ECONOMIC REVITALIZATION AND JOB CREATION QUESTIONNAIRE

1. Apart from job creation, how will the project and/or the associated technology development and deployment support economic revitalization?

2. How many jobs could potentially be created by the project and/or associated technology development and deployment? As applicable, please quantify in terms of number of jobs created per unit of product, number of jobs created per unit of waste remediated, number of jobs created per unit of emissions mitigated, and/or another appropriate metric.

3. What will be the nature of the created jobs, including the extent to which they will include clean energy jobs?

4. To what extent will the created jobs be at the prevailing wage?

5. To what extent will the created jobs be located in power plant and coal communities that are economically distressed and/or have been harmed by the adverse environmental impacts of the energy industry?

6. What recruitment strategies will be used for: a) workers from the local community, and b) individuals who belong to groups that are historically underserved or underrepresented?

7. Will the skills possessed by the existing labor force be adequate for the created jobs, or will training be required for those workers?

Appendix HH – 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[46] 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)[47], 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[48]. 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.

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

[46] 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/diversity/articles/how-energy-justice-presidential-initiatives-and-executive-orders-shape-equity

[47] https://www.federalregister.gov/documents/2021/02/01/2021-02177/tackling-the-climate-crisis-at-home-and-abroad

[48] See above for guidance on the definition and tools to locate and identify disadvantaged communities.

efforts in diversity, equity, inclusion, and accessibility. In this context, efforts toward DEIA are defined as:[49]

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 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.

[49] 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

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 answer the questions in the "Environmental Justice Questionnaire" located in **Appendix FF**.

Workforce

The Workforce section of the R&D Community Benefits Plan should answer the questions in the "Economic Revitalization and Job Creation Questionnaire" located in **Appendix GG**.

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?