FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

FLEXIBLE CARBON CAPTURE AND STORAGE (FLECCS)

Announcement Type: ~~Initial Announcement~~ Modification 01
Funding Opportunity No. DE-FOA-0002220
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	November 14, 2019
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, December 13, 2019
Submission Deadline for Concept Papers:	9:30 AM ET, December 23, 2019
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	9:30 AM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	TBD
Total Amount to Be Awarded	Approximately $43 million, subject to the availability of appropriated funds to be shared between FOAs DE-FOA-0002220 and DE-FOA-0002221.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

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

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

MODIFICATIONS

All modifications to the Funding Opportunity Announcement (FOA) are highlighted in yellow in the body of the FOA.

Mod. No.	Date	Description of Modifications
01	12/6/2019	• Clarified language on Applicant eligibility with regards to the FLECCS program and the Solicitation on Topics Informing New Program Areas Topic I. See section III.A of the FOA.

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REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: ○ Concept Summary ○ Innovation and Impact ○ Proposed Work ○ Team Organization and Capabilities	Mandatory	IV.C	9:30 AM ET, December 23, 2019
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]	Optional	IV.E	5 PM ET, TBD

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

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

"(A) to enhance the economic and energy security of the United States through the development of energy technologies that result in—
(i) reductions of imports of energy from foreign sources;
(ii) reductions of energy-related emissions, including greenhouse gases; and
(iii) improvement in the energy efficiency of all economic sectors; and
(B) to ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies."

ARPA-E issues this Funding Opportunity Announcement (FOA) under the programmatic authorizing statute codified at 42 U.S.C. § 16538. The FOA and any awards made under this FOA are subject to 2 C.F.R. Part 200 as amended by 2 C.F.R. Part 910.

ARPA-E funds research on and the development of high-potential, high-impact energy technologies that are too early for private-sector investment. The agency focuses on technologies that can be meaningfully advanced with a modest investment over a defined period of time in order to catalyze the translation from scientific discovery to early-stage technology. For the latest news and information about ARPA-E, its programs and the research projects currently supported, see: http://arpa-e.energy.gov/.

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

ARPA-E funds technology with the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from

the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have the clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

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

B. PROGRAM OVERVIEW

1. FOA SPECIFIC DEFINITIONS

Power Generator: means a system that converts a carbon-containing fuel to electricity with a capacity of at least 50 megawatts (MW); integrating the output of multiple generators is acceptable.

CCS Plant: means a system that separates carbon dioxide (CO_2) from the flue gas at a power generator and converts it into supercritical CO_2 suitable for transport in a pipeline[2] (i.e., CO_2 capture and compression).

[1] OMB Circular A-11 (https://www.whitehouse.gov/wp-content/uploads/2018/06/a11_web_toc.pdf), Section 84, pg. 3.
[2] K. Havens, Kinder Morgan, Pipelines-The Safest Way to Travel for CO2, https://lptest381.files.wordpress.com/2018/06/ken-havens-ccus-10-16-18-final.pdf (2018)

Full Plant: means a system comprised of a power generator and CCS plant that converts carbon-containing fuel to electricity and captures and compresses CO_2 for pipeline transport

Capacity Expansion Model: means a model that estimates the evolution of the electricity-generating portfolio of a grid as a function of time and across various technologies and policy scenarios.

Locational Marginal Pricing: or LMP represents market clearing price in wholesale electric energy markets; it is defined as the marginal cost to deliver 1 MW (increment or decrement) to a particular location in the power grid.

Levelized Cost of Electricity: or LCOE represents the cost of electricity over the life of the system and is defined as:

$$\text{LCOE}=\frac{(\text{Capital Cost})(\text{Capital Recovery Factor})+\text{Fixed O\&M}}{(\text{Capacity Factor})(\text{Net Plant Capacity})(8760)}+(\text{Heat Rate})(\text{Fuel Cost})+\text{Variable O\&M} \tag{1}$$

Where the capital recovery factor is defined as:

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{2}$$

For this FOA, ARPA-E is defining *i*, the discount rate, to be 10% and *n*, system lifetime, to be 30 years.

Net Present Value: or NPV equals the present value of cash flows minus the present value of invested cash (or outflows) and is defined as:

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t} \tag{3}$$

With R_t as net cash inflows/outflows during a single period, t.

2. OBJECTIVE

The objective of the FLExible Carbon Capture and Storage (FLECCS) program is to fund the development of carbon capture and storage (CCS) technologies that enable power generators to be responsive to grid conditions in a high variable renewable energy (VRE) penetration environment. This includes retrofits to existing power generators as well as greenfield systems with a carbon-containing fuel input and electricity as an output (i.e., a "black box" in which the nature of the fuel-to-electricity conversion process is not prescribed).

The value of such CCS technologies will be evaluated by their impact on the system LCOE of a net-zero carbon electricity grid, as determined by capacity expansion modeling. ARPA-E does not expect every CCS technology itself to be a net-zero carbon process; instead the cost and performance of each project selected under this FOA will be evaluated in the context of a net-zero carbon system which may include negative emission assets. Recent work suggests that a system LCOE of $75/MWh for a net-zero carbon electricity system is aggressive yet possible[3].

The development of CCS technologies is complicated by changes in the electrical grid that are largely the result of the increasing penetration of VRE sources such as wind and solar power. Correspondingly, changing market signals are resulting in operational challenges such as increased ramping of electricity generators. An example of the impact of fluctuating LMPs on the dispatch of a natural gas combined cycle (NGCC) power generator is shown in Figure 1. In response to the LMPs, the power generator varied its output between 200 and nearly 600 MW on a daily basis. Such frequent ramping has several disadvantages, including reduced capacity factor, increased operations and maintenance (O&M) costs, reduced power generator efficiency, and the potential for increased CO_2 emissions during ramping even if integrated with a CCS plant. Although this is only an example for one power generator and one month in 2018, it portends the impact of changing LMP trends on power generator operations, and the need to reconsider the design and operation of CCS processes accordingly.

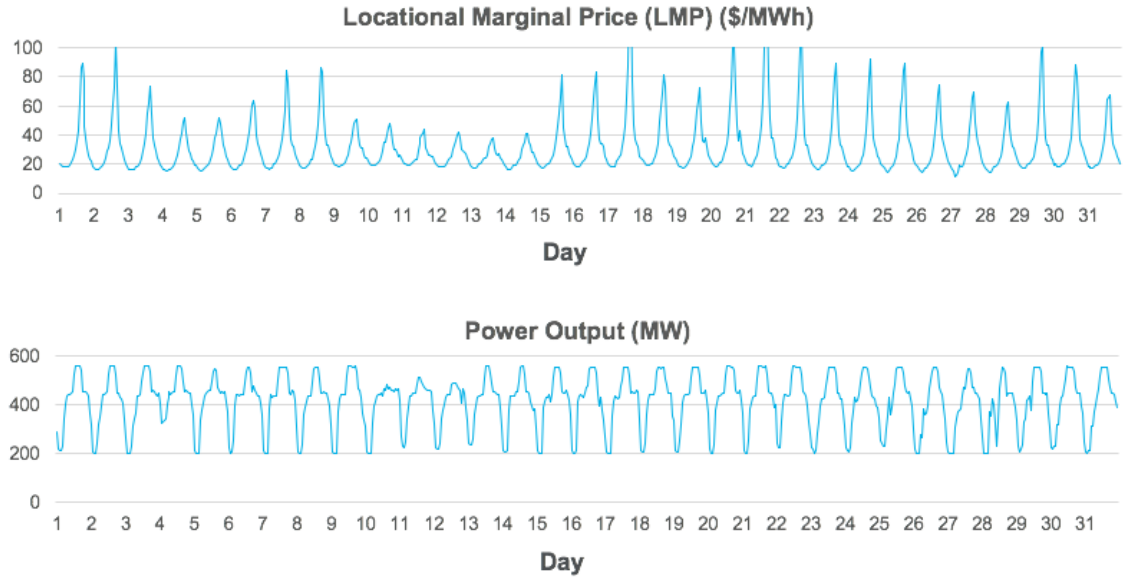

Figure 1: Day-ahead LMP[4] and the ultimate power output[5] of the Wolf Hollow II Generating Station in August 2018

Predicting future market structures as VRE generators continue to proliferate (and therefore,

[3] N.A. Sepulveda, et al., Joule 2, 1-18 (2018)
[4] Data from http://www.energyonline.com/Data/GenericData.aspx?DataId=23&ERCOT___Day-Ahead_Price
[5] Data from https://ampd.epa.gov/ampd/

precisely what LMPs will look like in the future) is impossible; however, future operational requirements and future market structures will impact the development and deployment of technologies such as CCS-equipped electricity generators. Even though the discussion below of LMP trends does not capture all the revenue streams an electricity generator could receive, energy pricing data from grid planning and load forecast tools can be used to infer general characteristics of technologies that will be valuable in a future energy system.

For example, one literature report examined grids in California and Texas assuming 50% VRE penetration[6]. The resulting LMPs for two days in March 2030 are shown in Figure 2.

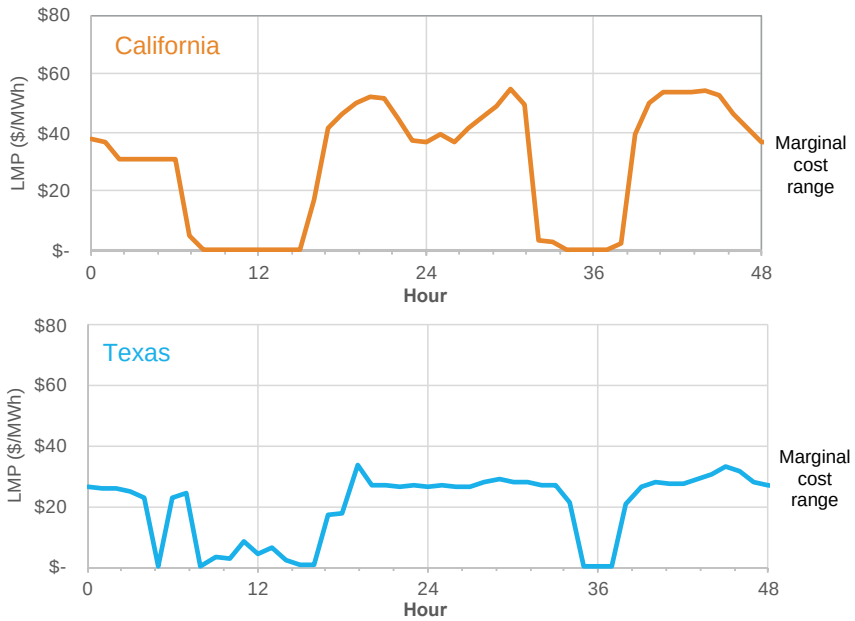

Figure 2: Projected LMPs in California and Texas in March 2030, with 50% VRE penetration[6]. The gray sections represent a range of marginal costs for a power generator with CCS.

In the California example, the LMP oscillates above and below the marginal cost to run a power generator equipped with CCS. The low-to-negative midday LMPs result from the correlated power production of zero-marginal cost solar resources. A power generator in a region with such LMPs would likely cycle daily.

In the Texas example, there are similar diurnal oscillations but also a generally depressed LMP, which is due to a combination of high wind output and lower loads in Texas in March. In this case, the power generator could cycle daily, or be shut down if the LMP is projected to be lower than the marginal cost to operate the plant for more than several hours.

This FOA is structured within the context of a deregulated electricity system with market structures. However, the electricity system trends and concepts described herein apply to

[6] J. Seel, et al., Impacts of High Variable Renewable Energy Futures on Wholesale Electricity Prices, and on Electric-Sector Decision Making, https://emp.lbl.gov/publications/impacts-high-variable-renewable (2018)

vertically-integrated regions as well, and the technologies developed in the FLECCS program are intended to be applicable to all regions within the U.S.

FLECCS addresses a tension that will become more severe as electricity systems decarbonize: that firm low-carbon resources such as CCS-equipped plants can lower the cost of a net-zero carbon system, yet electricity market trends such as the ones shown in Figure 2 complicate CCS design, operations, and commercialization potential. This tension will be discussed in detail below.

3. PROGRAM STRUCTURE

FLECCS is a two-phase program. By default, Applicants should provide detailed budgets and task descriptions that cover both Phase 1 and Phase 2. However, applications that propose detailed budgets and task descriptions for Phase 1 only will also be considered for selection (e.g., an Applicant faces large uncertainty about potential technology development pathways in Phase 2).

Phase 1 focuses on designing and optimizing innovative CCS processes that enable flexibility on a high-VRE grid. Project Teams will assess process performance by maximizing the NPV of a power generator with CCS, given LMP price signals that reflect such a grid as well as a range of carbon abatement cost scenarios defined below. These LMP signals will be provided as an input from ARPA-E prior to project commencement.

Phase 1 will last for approximately 15 months and have will have a total budget of approximately $7 million in Federal funding. All selected projects, including those that provided detailed budgets and task descriptions for both Phase 1 and Phase 2, will initially be obligated funding for Phase 1 only. Under a separate FOA (Solicitation on Topics Informing New Program Areas FOA: Topic I, DE-FOA-0001953), ARPA-E will fund the development of a capacity expansion modeling tool that estimates the build-out and utilization of each CCS process designed under Phase 1, under a range of possible scenarios.

At the end of Phase 1, ARPA-E will conduct an engineering design review with external reviewers to analyze the processes designed by Project Teams. In addition, ARPA-E will analyze the market potential of the proposed technologies using the modeling tool developed under DE-FOA-0001953.

Based primarily on the technical success of the individual projects, the engineering design review, and the capacity expansion analysis, ARPA-E will select projects to continue to Phase 2, subject to the availability of appropriated funds. If selected by ARPA-E for Phase 2, it is possible that an Applicant that proposed Phase 1 and Phase 2 in its submission to this FOA could move immediately to Phase 2 upon completion of Phase 1. Awards resulting from this FOA that proposed Phase 1 only may, if selected by ARPA-E for Phase 2, be renewed by, for example, negotiating a new award, adding one or more budget periods, and/or extending the period of performance of the initial award.

Phase 2 will focus on building components, unit operations, and small prototype systems to reduce the technical risk and cost associated with these CCS systems. Phase 2 will last for approximately 3 years and have a total budget of approximately $36 million in Federal funding.

4. BACKGROUND

The U.S. electricity grid is evolving towards a lower-carbon system. As of May 2019, at least seven states and large utilities had committed to achieve a net-zero carbon system, in most cases by 2050[7]. In the time since, utilities such as Duke Energy, NRG, and DTE Energy announced similar commitments. One utility with such a target, Xcel Energy, maintains that an 80 percent reduction in CO_2 emissions relative to a 2005 baseline is possible by 2030 with technologies available today[8]. The utility noted, however, that achieving a 100 percent carbon-free system would require "new carbon-free dispatchable technologies — technologies not yet commercially available at the cost and scale needed to achieve our 2050 aspiration. Because of this, there needs to be significant research and development to ensure we have these technologies to deploy in the coming decades."

Several studies have shown that the cost of a net-zero carbon system could be reduced with firm low-carbon generators such as a CCS-equipped power generator, compared to a system powered by 100 percent renewable electricity[3,9,10]. The deployment of such resources, however, depends on a range of factors such as wind and solar resources in a given region, CCS capital costs, CO_2 capture rate, and technology assumptions for other technologies such as energy storage and nuclear power[3].

As mentioned above, FLECCS aims to address the disconnect between the potential value of CCS-equipped power generators in a deeply decarbonized grid, and the economic and operational pressure power generators face in light of increasing VRE penetration (even without CCS). For example, Figure 3 shows a review of several studies that estimated how the capacity factor of NGCC plants will change with VRE penetration[11]. Although the magnitudes vary, each study shows a decrease in NGCC capacity factor with increasing VRE penetration.

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[7] Clean Air Task Force, https://www.catf.us/wp-content/uploads/2019/05/State-and-Utility-Climate-Change-Targets.pdf

[8] Building a Carbon-Free Future, Xcel Energy https://www.xcelenergy.com/staticfiles/xe/PDF/Xcel%20Energy%20Carbon%20Report%20-%20Feb%202019.pdf (2019)

[9] C.F. Heuberger, et al., Energy Procedia 114, 7564-7572 (2017)

[10] A. Boston, et al., Managing Flexibility Whilst Decarbonising Electricity, http://anlecrd.com.au/wp-content/uploads/2017/07/Managing-Flexibility-NEM-2017-Report.pdf (2017)

[11] R. Wiser, et al., Impacts of Variable Renewable Energy on Bulk Power System Assets, Pricing, and Costs, https://emp.lbl.gov/sites/default/files/lbnl_anl_impacts_of_variable_renewable_energy_final.pdf (2017)

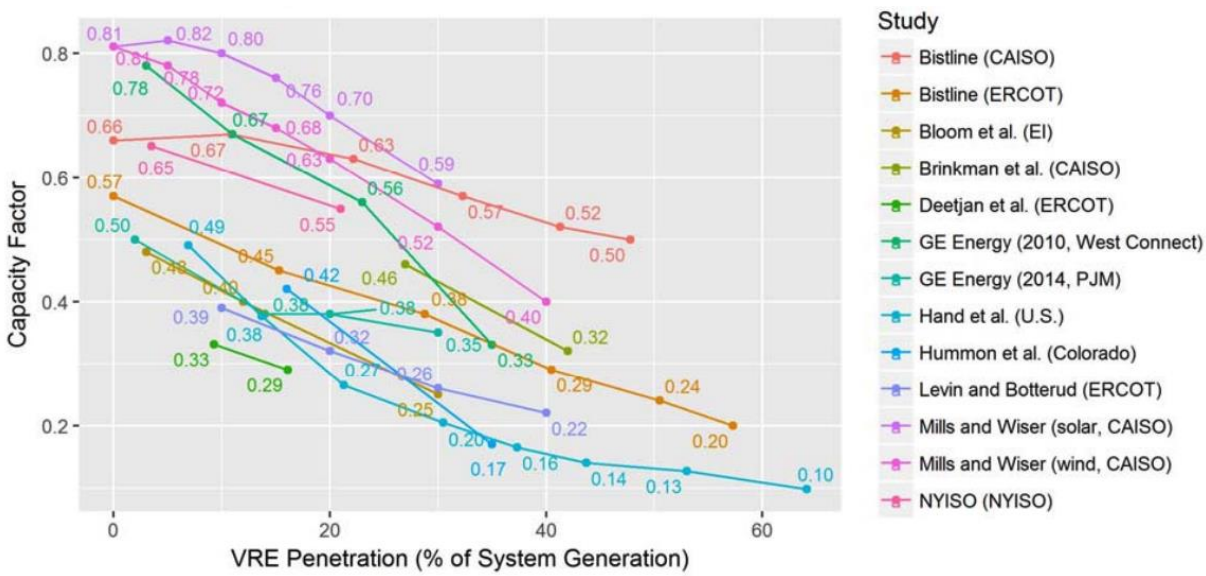

Figure 3: NGCC capacity factor as a function of VRE penetration across multiple studies in the literature (identified in the legend)[11]

Using data from the NETL Cost and Performance Baseline study[12] one can see, for example, the impact of reduced capacity factor on the LCOE of an NGCC plant equipped with CCS:

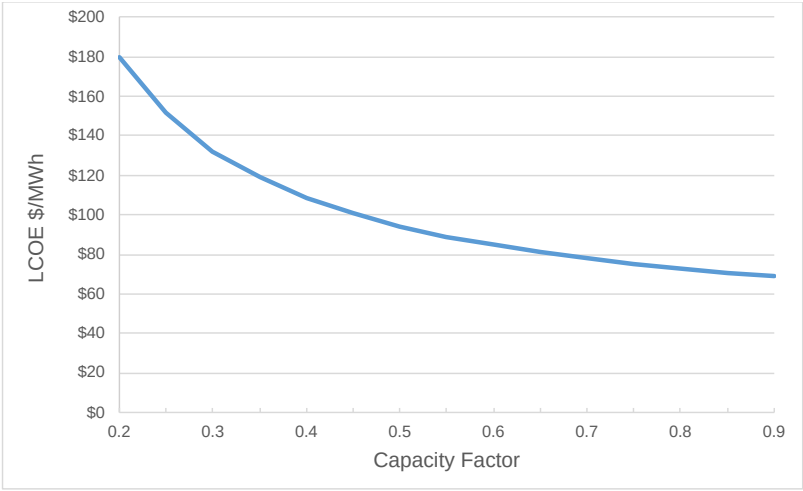

Figure 4: LCOE as a function of capacity factor for a NGCC power generator equipped with CCS (data from Ref. 12). The baseline capacity factor in that study was assumed to be 85%.

In addition to these economic challenges, increasing VRE penetration presents technical challenges for a CCS-equipped power generator. Although the power generator might be

[12] R. James, et al., Cost and Performance Baseline for Fossil Energy Plants Vol. 1, https://www.netl.doe.gov/projects/files/CostAndPerformanceBaselineForFossilEnergyPlantsVol1BitumCoalAndNGtoElectBBRRev4-1_092419.pdf (2019)

flexible, the ability of a CCS plant to handle variable mass and heat flows is uncertain. Current commercial CCS operations, including the NRG Petra Nova and SaskPower Boundary Dam 3 facilities, operate under baseload conditions. There are, however, studies in the literature examining dynamic CCS operations at several pilot facilities in Europe[13,14,15,16]. Broadly, those studies revealed that although dynamic operation required the optimization of numerous parameters, the CCS plants generally were capable of load following and handling a range of plant operating conditions. However, the dynamic operating conditions in those studies were limited in extent; NGCC power generators, for example, can turn down to less than 25 percent of the maximum power output. CCS systems have not been designed for such operating conditions.

Given these market trends, CCS process designs and operations should be reconsidered in order to ensure that they can contribute to a low-cost, net-zero carbon electricity system, even if a given CCS process itself is not net-zero. There are several pathways by which this might be achieved. The following examples are for illustrative purposes only; they are not intended as suggestions for specific project concepts for Applicants.

First, CCS processes could be redesigned to be as flexible as possible, so as to follow the power generator as it varies its output in response to market conditions. Under this example, the CCS plant designs would need to consider startup, ramping, turndown, and shutdown, and there are existing data for power generator flexibility characteristics such as ramp rate and turndown[17,18,19].

A cryogenic air separation unit (ASU) used as part of an oxycombustion process, for example, takes several hours to start up[20], which would result in excessive CO_2 emissions for a power generator with frequent starts and stops. Researchers have considered means to improve ASU flexibility, including storage vessels to collect liquid that drains from the argon column[21], liquid oxygen storage[22], and preemptive dynamic controls[23].

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[13] P. Tait, et al., Int'l J. Greenhouse Gas Contr. 48, 216-233 (2016)
[14] J. Gaspar, et al., Energy Procedia 86, 205-214 (2016)
[15] P. Tait, et al., Int'l J. Greenhouse Gas Contr. 71, 253-277 (2016)
[16] M. Bui, et al., Int'l J. Greenhouse Gas Contr. 79, 134-153 (2018)
[17] N. Ferrari, et al., Operating Flexibility of Power Plants with CCS, IEAGHG Report 2012/6 (2012)
[18] M.A. Gonzalez-Salazar, et al., Renew. Sus. Energy Rev. 82, 1497-1513 (2018)
[19] PJM Minimum Operating Parameters Under Capacity Performance, https://www.pjm.com/~/media/committees-groups/committees/mic/20160119-special/20160119-capacity-performance-parameter-limitations-informational-posting.ashx (2015)
[20] A.R. Smith, J. Klosek, Fuel Processing Tech. 70, 115-134 (2001)
[21] J. Miller, et al., Ind. Eng. Chem. Res. 47, 394-404 (2008)
[22] J.-P. Tranier, et al., Energy Procedia 4, 966-971 (2011)
[23] Y. Cao, et al., AIChE Journal 63, 3845-3859 (2017)

Another report described how optimal scheduling and advanced controls can improve the profitability of a CCS-equipped power generator[24]. A review[25] of dynamic modeling and optimization highlighted design and operational factors that would have to be considered to enable a flexible solvent process, including:

- Lean solvent loading
- Flowrates in the absorber and regenerator
- Liquid-to-gas ratio in the absorber and regenerator
- Temperature and pressure (including gradients) in the absorber and regenerator
- Sizing of the CCS plant relative to the power generator
- Heat source: integration with the power generator steam cycle or a separate cogeneration facility

When designing a load-following CCS process, additional factors to consider are the tradeoffs between capital costs and operational costs. For a baseload process, a lower LCOE might be achieved by investing additional capex in order to improve efficiency. As capacity factor decreases, however, the LCOE become more sensitive to capital and fixed O&M costs because they become amortized over fewer hours. This can be seen in Figure 5, which shows the same curve using NETL data as in Figure 4, but includes a second curve with arbitrarily-selected values of a 40 percent capex reduction and 10 point decrease in power generator efficiency. At higher capacity factors, the two curves are nearly equal. But as capacity factor decreases the adjusted curve—even though it is less efficient—has a lower LCOE because the impact of capex and fixed O&M being amortized over fewer hours is dampened.

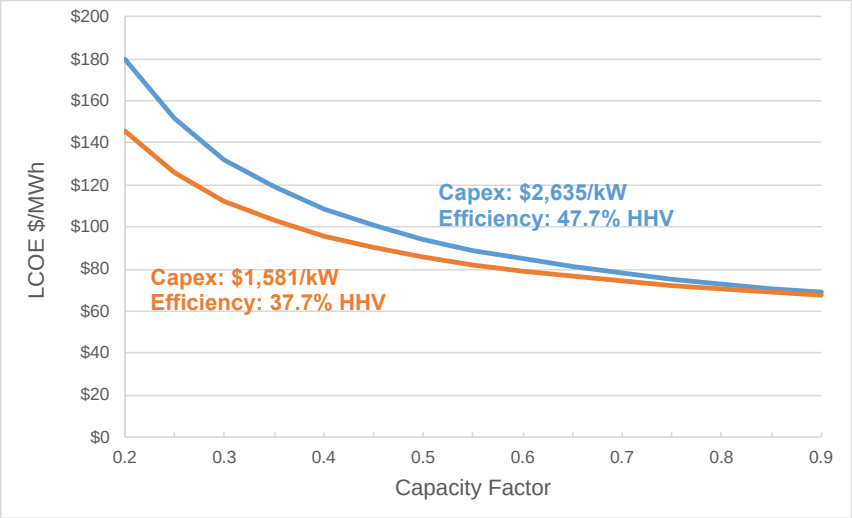

Figure 5: LCOE as a function of capacity factor for NGCC with CCS in the NETL base case[12] (blue line, identical to Figure 4) and a plant with arbitrarily-chosen values of 40 percent capex reduction and a 10-point decrease in efficiency (orange line)

[24] T. Bankole, et al., Computers and Chem. Eng. 109, 30-47 (2018)
[25] M. Bui, et al., Computers and Chem. Eng. 61, 245-265 (2014)

Another strategy to accommodate fluctuating LMPs is to operate the power generator and CCS plant under more steady-state conditions, but shift the generated electricity such that it is exported to the grid only at times when the LMP is greater than the marginal cost to operate the plant. The first concepts of operations for high-LMP times were temporarily venting CO_2 to the atmosphere or capturing CO_2 but storing the solvent for regeneration at a later time[26,27,28]. The venting strategy is economical only if the LMP (in $/MWh) is several times higher than the carbon price (in $/ton). The solvent storage approach improves short-run profits, but the capital required for storage tanks and additional solvent (which is sensitive to solvent degradation rates) limits the duration to 30 minutes per day[28]. An alternate approach is to effectively store CO_2 in solvent by varying the loading rate in response to LMP; this approach was projected to be more economical than solvent storage because it did not require the extra capital for storage tanks and extra solvent[29]. Another concept to operate the full plant under steady-state conditions but shift the electricity output is to employ other forms of storage, such as thermal energy storage. This could have the additional benefit of reducing costs and emissions associated with frequent cycling of the full plant, if the added capital costs of storage could be minimized[30].

One concept common to the potential technologies mentioned above is capital cost reduction. Regardless whether applicants focus on load-following or low-/non-load-following designs, reducing the capital cost of CCS-equipped power generators is paramount to being built and dispatched in a future electricity system.

C. TECHNOLOGIES OF INTEREST

Potential FLECCS projects include retrofits to existing power generators as well as greenfield systems that have a carbon-containing fuel input and electricity as an output (i.e. a "black box" in which the nature of the fuel-to-electricity conversion process is not prescribed). As noted below, processes that are designed primarily to remove CO_2 from the atmosphere, but can change modes to export electricity to the grid, will be considered for selection.

Based on trends in the electricity grid described above, especially the falling cost of VRE generators and energy storage, ARPA-E expects that compelling CCS process attributes could include, but are not limited to:

[26] J.R. Gibbins, R.I. Crane, Proc. Inst. Mech. Engrs. 218, 231-239 (2004)
[27] H. Chalmers, J.R. Gibbins, Fuel 86, 2109-2123 (2007)
[28] S.M Cohen, et al., Energy Procedia 4, 2604-2611 (2011)
[29] N. Mac Dowell, N. Shah, Energy Procedia 63, 1525-1535 (2014)
[30] S. Hume, Thermal Energy Storage, presented at the ARPA-E Flexible CCS Workshop, https://arpa-e.energy.gov/sites/default/files/1.7%20ARPAe%20Carbon%20Capture%20Workshop%20-%20TES%20Final.pdf (2019)

- Lower CCS capital costs, even if that entails some increase in marginal cost including parasitic load (given trends towards lower power generator capacity factor)
- CCS processes that enable maximal power generator flexibility such as ramp rate, turndown, and startup and shutdown time
- CCS systems that include additional processes that enable a power generator to shift the export of electricity to the grid, thereby allowing the power generator and CCS plant to operate under more steady-state conditions even when subjected to fluctuating LMPs. Examples include but are not limited to energy storage and hydrogen production; the latter would be constrained to a scale compatible with current combustion system (gas turbine or internal combustion engine) and natural gas pipeline infrastructure
- CCS processes that can cost-effectively achieve high CO_2 capture rates from flue gas (e.g. greater than 90% removal) and/or vary their capture rate based on market conditions
- Designs that increase the utilization of a point-source CCS process, such as integration with direct air capture (DAC) systems
- Processes that are designed primarily to remove CO_2 from the atmosphere, but can change modes to export electricity to the grid in times of high demand

1. PHASE 1

The work in Phase 1 will proceed according to Figure 6:

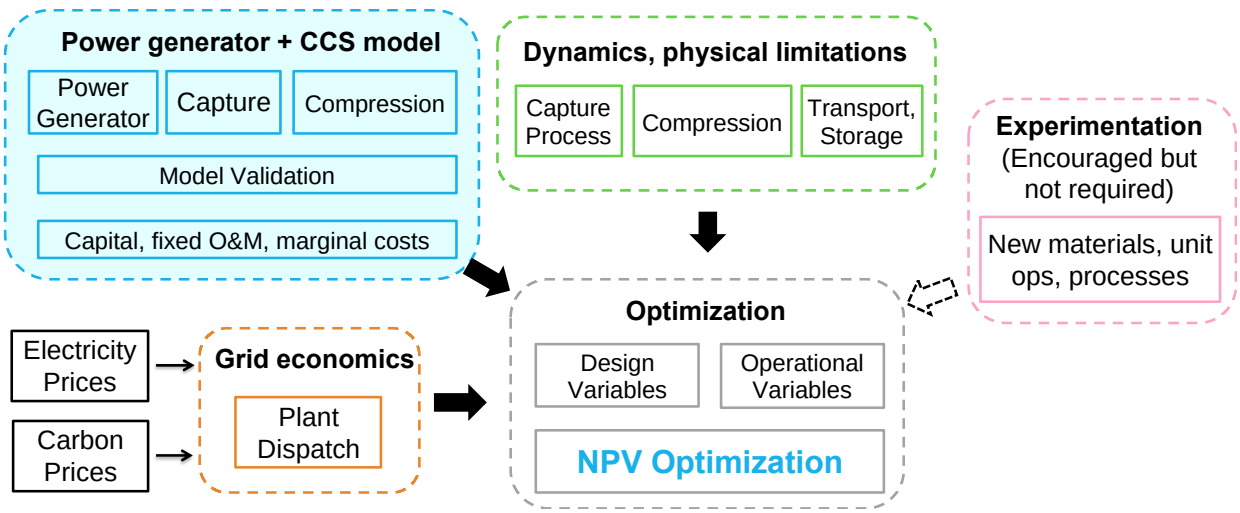

Figure 6: Schematic of tasks to be performed in Phase 1. The boxes in black, electricity prices (LMPs) and carbon prices, will be supplied to Project Teams by ARPA-E.

First, Project Teams will build models of the power generator, CO_2 capture plant, and CO_2 compression systems, and validate those models. Applicants are encouraged to leverage existing models. For example, the NETL Cost and Performance Baseline report has data for NGCC, post-combustion coal, and integrated gasification combined cycle (IGCC) systems[12]. Furthermore, NETL has developed open-source tools such as process and system models under the Carbon Capture Simulation Initiative (CCSI), Carbon Capture Simulation for Industry Impact

(CCSI[2]), and Institute for the Design of Advanced Energy Systems (IDAES)[31]. Project Teams will also estimate the capital, fixed O&M, heat rate, and variable O&M.

Second, the dispatch of the power generator will be defined by each Project Team using all or a subset of hourly day-ahead LMP data—provided by ARPA-E—that reflects a grid with a large VRE penetration. Again, applicants must use published values of power generator flexibility (see, for example, Refs. 17-19) unless they are proposing a new power generator. For example, a Project Team may decide to dispatch the power generator in a load-following manner, e.g. dispatching when the LMP is greater than the marginal cost to run the full plant and either turning down or shutting off when the LMP is lower than the full plant's marginal cost. Or, Project Teams may choose to operate both the power generator and the CCS unit in a limited- or non-load-following manner to run under the power generator and CCS plant under more steady-state conditions. As noted above, this could be done by using an additional technology—such as energy storage or hydrogen production at a volume consistent with existing combustion turbine and pipeline infrastructure—to buffer the output to the grid so that the plant is not selling electricity to the grid at a loss.

Dispatch will be analyzed using carbon abatement costs of $100, $200, and $300 per ton CO_2. These values are chosen to represent a range of CO_2 removal costs from the atmosphere[32,33], as some amount of DAC would likely be used to achieve a net-zero carbon grid. The carbon pricing is thus chosen to represent a range of prices in which DAC technologies could clear the market.

Third, process dynamics and physical limitations will be considered. Transient supply during CO_2 injection may lead to sudden changes in pressure, temperature and density causing dry ice and/or CO_2 hydrate formation, possible blockage of injector outlet and fracture of pipe casing[34,35]. Applicants are encouraged to seek technical solutions for flexible CO_2 supply/transport to maintain wellbore integrity and reduce pipe fatigue and corrosion.

Fourth, applicants are encouraged to consider experimentation to support the design and optimization of CCS processes, especially if those processes rely on novel unit operations and/or materials with properties beyond the state of the art. <u>Experimentation in Phase 1 is encouraged but not required.</u>

Finally, Project Teams will use the full plant costs, LMP data, and full plant dispatch profile to optimize the process configuration and design and operational variables in order to maximize NPV. Because this is a simplified analysis that considers only LMP revenue and not additional

[31] David Miller, NETL, Presented at ARPA-E Flexible CCS Workshop, https://arpa-e.energy.gov/sites/default/files/2.3%20Miller-NETL-CCSI-IDAES-ARPA-E%20Workshop%20%28final%29.pdf (2019)
[32] D.W. Keith, et al., Joule 2, 1573-1594 (2018)
[33] J. Larsen, et al., Capturing Leadership: Policies for the US to Advance Direct Air Capture Technology, https://rhg.com/wp-content/uploads/2019/05/Rhodium_CapturingLeadership_May2019-1.pdf (2019)
[34] R. Samuel and H. Mahgerefteh, Int'l. J. Chem. Eng. Appl. 8, 319-326 (2017)
[35] M.D. Jensen, et al., Energy Procedia 63, 2715-2722 (2014)

payments such as capacity, ancillary services, uplift, etc., processes with positive NPVs are not anticipated. However, the objective function of maximizing NPV will help identify technology attributes that will be valuable in a future energy system.

One example of such an undertaking in the literature, for example, was to optimize a membrane process for adjusted 2015 California electricity prices[36]. In that work, the authors studied the impact of varying 12 design and operational variables on NPV given variable LMPs. But only one process configuration—a 2-stage membrane process with no downstream purification unit—was considered.

Since the constraints in this FOA—particularly the electricity market and carbon pricing conditions—are different than prior ARPA-E[37] and National Energy Technology Laboratory (NETL)[38] FOAs, ARPA-E anticipates that optimal technology solutions could differ substantially from a CCS process tailored for 90 percent CO_2 capture from a power generator operating under baseload conditions. Applicants are thus encouraged to consider advanced optimization techniques that allow for a broader range of process configurations and design and operational variables to be considered without sacrificing accuracy, and in a computationally-tractable manner. Examples include, but are not limited to:

- Approximation-assisted optimization[39]
- Surrogate-based optimization[40,41]
- Dimension-reduction techniques[42]
- Advanced design tools to identify high-performance, non-obvious designs[43]

The primary revenue for the NPV calculation is electricity sales. As discussed in "Submissions Specifically not of Interest", Section III.C.3 of the FOA below, solutions that rely on CO_2 utilization or coproduction for revenue will not be considered for selection.

2. PHASE 2

Phase 1 will identify full plant process designs and operations that minimize the system LCOE of a net-zero carbon electricity system. Phase 2 will focus on building components, unit operations, and small systems to reduce the technical risk and cost associated with such CCS systems. Further information is provided in Section I.D below.

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[36] M. Yuan, et al., Int'l. J. Greenhous Gas Cont. 84, 154-163 (2019)
[37] Innovative Materials and Processes for Advanced Carbon Capture Technology (IMPACCT), DE-FOA-0000208, https://arpa-e-foa.energy.gov
[38] https://www.netl.doe.gov/business/solicitations
[39] O. Abdelaziz, et al., HVAC&R Research 16, 707-728 (2010)
[40] M. Kaya, S. Hajimirza, Nature Scientific Reports 8, 8170 (2018)
[41] Y.H. Lee, et al., Structural & Multidisciplinary Optimization 60, 99-116 (2019)
[42] D.J. Lohan, et al., Structural & Multidisciplinary Optimization 55, 1063-1077 (2017)
[43] J., Choe, J. Kim, Composite Structures 158, 333-339, (2016)

D. TECHNICAL PERFORMANCE TARGETS

The utility of the CCS technologies developed in the FLECCS program will be evaluated in the context of a net-zero carbon grid, with a system LCOE target of $75/MWh, as discussed above. Project Teams will design and optimize CCS systems with the objective of maximizing NPV, using all or a subset of LMP data provided by ARPA-E. The NPV will be calculated for the following carbon prices: $100, $200, and $300 per ton CO_2.

ARPA-E is not establishing a CO_2 removal percentage target. Project Teams will maximize NPV given the LMP signals and carbon prices, and the optimal solution will have a corresponding carbon intensity, integrated over at least one year of operation. The cost and plant performance, data will be used in the capacity expansion model to analyze the value of a given CCS process to a net-zero carbon grid.

Each applicant must provide the information requested in Table 1 and Table 2 in their submission. Table 1 provides a list of attributes that the applicant's technology must address to meet the metrics of FLECCS FOA. Applicants must also describe why their proposed approach and technology are superior to the state of the art (SOA). Applicants should use Ref. 12 as the default for SOA values other than fuel costs (see values below); deviations are allowed but must be substantiated through references, data, models, or analytical calculations. Applicants proposing a process with natural gas or coal as the fuel must use the following prices:

- Natural gas: $3.50/MMBtu[44]
- Coal: $1.94/MMBtu[45,46]

Table 1: Technology differentiator matrix

Attribute	SOA Value	Proposed Value	Description / Justification
Power generator type[A]	n/a	n/a	
CCS plant technology	n/a	n/a	
Capital cost[B]			
Fixed O&M cost			
Variable O&M cost			
Power generator heat rate			
Flexibility enabler[C]	n/a	n/a	
Capture rate[D]			

[44] https://www.eia.gov/dnav/ng/hist/n3045us3A.htm
[45] https://www.eia.gov/coal/annual/
[46] https://www.eia.gov/tools/faqs/faq.php?id=72&t=2

- [A]Include the primary fuel for operation (natural gas, coal etc.) and whether your proposed solution is a greenfield full plant or a CCS retrofit on an existing power generator, using Ref. 12 as a baseline.
- [B]If a greenfield plant, this value should include the power generator and CCS plant; if a retrofit it should include the CCS plant and upgrades to the power generator, if required.
- [C]Describe how the proposed technology will enable the full plant to respond to variable LMPs and a reduced capacity factor.
- [D]Project the CO_2 capture rate for emissions integrated over at least one year of operation.

Table 2 provides a list of subject matter expertise that the applicant team is expected to demonstrate for Phase 1.

Table 2: Subject matter expertise matrix

Subject matter expertise	Team member(s) responsible	Description / Justification
CCS technology[A]		
Process modeling[B]		
Economic analysis[C]		
Optimization[D]		
Power generation[E]		

- [A]Both computational modeling and experimentation skills are desired.
- [B]Project Teams should demonstrate expertise in process modeling including steady-state and dynamic modeling of full plant operation and controls. Describe tools that will be used to conduct this work in Phase 1.
- [C]Project Teams should demonstrate expertise in economic/costing analysis for complex systems such as power generators and CCS plants.
- [D]Project Teams should demonstrate design, thermo-economic and techno-economic optimization skills needed for successful accomplishment of Phase 1 objectives. Describe tools that will be used for this work.
- [E]Only required if the applicant is proposing a novel power generation technology that is not commercially available.

Each Applicant proposing a detailed budget and task descriptions for Phase 1 and Phase 2 must also include the information requested in Table 3 in their submission, identifying the aspects of their technology with the highest anticipated cost and performance risks, and the experimental work they propose for Phase 2 to reduce those risks.

Table 3: Anticipated cost and performance risks to be addressed in Phase 2 (for applicants proposing Phase 1 and Phase 2 only)

Cost or performance risk	Novelty of proposed approach	Experimental strategy to reduce cost and performance risk
[Risk #1]		
[Risk #2]		
[Applicants to decide how many risks to include]		

Phase 2 experimental details must include:

- Nature of the prototype (e.g., component, unit operation, system, etc.)
- Schematic diagram of the anticipated prototype
- Approximate size of the prototype (e.g., sizing relative to equivalent plant power, flue gas flow rate, etc.)
- Exhaust conditions (e.g., simulated flue gas or slipstream of real flue gas)

Furthermore, Phase 2 details must include the impact of the flexibility-enabling technology on the system. For example, a load-following solvent process would have implications for solvent management, degradation rates, equipment reliability, etc.

In order to evaluate the impact of a given CCS technology at the system level, FLECCS Project Teams will be required to share cost and performance data with the team(s) funded under the Solicitation on Topics Informing New Program Areas: Topic I, DE-FOA-0001953 to input into a capacity expansion model that will be developed under that FOA. In order to ensure that this data is safeguarded, the team(s) funded under the Solicitation on Topics Informing New Program Areas: Topic I, DE-FOA-0001953 will be required to sign a non-disclosure agreement with respect to data received from each FLECCS Project Team unless a FLECCS Project Team agrees otherwise.

For each carbon price, Project Teams will report the data in Table 4 to ARPA-E at the end of Phase 1. This data will be reviewed by ARPA-E and a select group of external experts to analyze the market potential via the capacity expansion model under a range of scenarios.

Note that this table is being provided here to give applicants a sense of the data that will ultimately be used in the capacity expansion model; <u>applicants do NOT need to include a response to Table 4 in their submission</u>.

Table 4: Initial list of inputs for the capacity expansion model. "P" is a Primary metric and "S" is a Secondary metric, to convey the relative importance of a given metric for different types of solutions. All metrics are for the full plant unless otherwise specified.

Metric	Unit	Load-Following Solutions	Limited/Non-Load-Following Solutions	Notes (If Applicable)
Capital cost	$/kW	P	P	If a greenfield plant, this value must include the power generator and CCS plant; if a retrofit it must include the CCS plant and, if required, upgrades to the generator
Fixed O&M cost	$/kW-year	P	P	Use value from Ref. 12 or propose original value with supporting rationale. Factors such as material makeup costs and water usage must be considered.
Variable O&M cost	$/MWh	P	P	Use value from Ref. 12 or propose original value with supporting rationale
Heat rate	MMBtu/MWh	P	P	To be reported across a range of power generator operating levels between full output and maximum turndown
Carbon intensity	gCO_2/kWh	P	P	Reported as a function of output level or heat rate
Hot startup time	Minutes	P	S	Full plant offline for < 8 hours
Warm startup time	Minutes	P	S	Full plant offline for 8-48 hours
Cold startup time	Minutes	P	S	Full plant offline for > 48 hours
Shutdown time	Minutes	P	S	Time from 100% to 0 power output
Maximum turndown	% of maximum power output	P	S	Minimum power generating level
CCS plant ramp rate	% of maximum	P	S	From maximum turndown to full power output

	power generator output per minute			
Buffering duration	Hours	n/a	P	Maximum duration for which the power generator is operational but not exporting power to the grid

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $43 million available for new awards, to be shared between FOAs DE-FOA-0002220 and DE-FOA-0002221, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 10-25 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

Individual awards may vary between $250,000 and $10 million.

The period of performance for funding agreements may not exceed 51 months for Phase 1 and Phase 2 combined. ARPA-E expects the start date for funding agreements to be September 2020, or as negotiated.

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

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

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

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

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

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

B. RENEWAL AWARDS

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

C. ARPA-E FUNDING AGREEMENTS

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[47] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.C below.

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[48]

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

ARPA-E encourages Prime Recipients to review the Model Cooperative Agreement, which is available at http://arpa-e.energy.gov/arpa-e-site-page/award-guidance.

[47] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[48] The Prime Recipient is the signatory to the funding agreement with ARPA-E.

2. FUNDING AGREEMENTS WITH FFRDCS/DOE LABS, GOGOS, AND FEDERAL INSTRUMENTALITIES

Any Federally Funded Research and Development Centers (FFRDC) involved as a member of a Project Team must provide the information requested in the "FFRDC Lab Authorization" and "Field Work Proposal" section of the Business Assurances & Disclosures Form, which is submitted with the Applicant's Full Application.

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

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

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

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

3. OTHER TRANSACTIONS AUTHORITY

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

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

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

D. STATEMENT OF SUBSTANTIAL INVOLVEMENT

ARPA-E is substantially involved in the direction of projects from inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- Project Teams must adhere to ARPA-E's agency-specific and programmatic requirements.
- ARPA-E may intervene at any time in the conduct or performance of work under an award.
- ARPA-E does not limit its involvement to the administrative requirements of an award. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole.
- ARPA-E may, at its sole discretion, modify or terminate projects that fail to achieve predetermined Go/No Go decision points or technical milestones and deliverables.
- During award negotiations, ARPA-E Program Directors and Prime Recipients mutually establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. In addition, ARPA-E will negotiate and establish "Go/No-Go" milestones for each project. If the Prime Recipient fails to achieve any of the "Go/No-Go" milestones or technical milestones and deliverables as determined by the ARPA-E Contracting Officer, ARPA-E may – at its discretion - renegotiate the statement of project objectives or schedule of technical milestones and deliverables for the project. In the alternative, ARPA-E may suspend or terminate the award in accordance with 2 C.F.R. §§ 200.338 and 200.339.
- ARPA-E may provide guidance and/or assistance to the Prime Recipient to accelerate the commercial deployment of ARPA-E-funded technologies. Guidance and assistance provided by ARPA-E may include coordination with other Government agencies and nonprofits to provide mentoring and networking opportunities for Prime Recipients. ARPA-E may also organize and sponsor events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E may establish collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

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

Eligibility Restriction Regarding the Solicitation on Topics Informing New Program Areas: Topic I, DE-FOA-0001953.

An entity may submit separate applications to the Solicitation on Topics Informing New Program Areas: Topic I, DE-FOA-0001953 and FLExible Carbon Capture and Storage (FLECCS) DE-FOA-0002220 and/or FLExible Carbon Capture and Storage SBIR/STTR (FLECCS SBIR/STTR) DE-FOA-0002221 (collectively, the "FLECCS Program"). However, any individual participating on ~~if an entity receives~~ a Financial Assistance Award from ARPA-E under Solicitation on Topics Informing New Program Areas: Topic I, DE-FOA-0001953, ~~that entity~~ will be prohibited from participation on any FLECCS Project Team.

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[49] as the lead for a Project Team,[50] or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[51] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

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

[49] A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.
[50] A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.
[51] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

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

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

3. FOREIGN ENTITIES

U.S.-incorporated subsidiaries of foreign entities, whether for-profit or otherwise, are eligible to apply for funding under this FOA as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team, subject to the requirements in 2 C.F.R. § 910.124, which includes requirements that the entity's participation in this FOA be in the economic interest of the U.S. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate.

Entities not incorporated in the U.S., whether for-profit or otherwise, are not eligible to apply for funding, but may be proposed by an Applicant as a member of a Project Team.

All work under an ARPA-E award must be performed in the U.S. The Applicants may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

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

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

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;

- Provisions for members' cost sharing contributions; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

B. COST SHARING[52]

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

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.C.1 of the FOA). Under a Cooperative Agreement or Grant, the Prime Recipient must provide at least 20% of the Total Project Cost[53] as cost share, except as provided in Sections III.C.2 or III.C.3 below.[54]

2. INCREASED COST SHARE REQUIREMENT

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

Under an "other transaction" agreement, the Prime Recipient must provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this cost share requirement, as appropriate.

3. REDUCED COST SHARE REQUIREMENT

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

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is not required to provide cost share.
- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs/DOE Labs/Federal agencies and instrumentalities (other than DOE) are not required to provide cost share.
- Small businesses – or consortia of small businesses – may provide 0% cost share from the outset of the project through the first 12 months of the project

[52] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[53] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.
[54] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

(hereinafter the "Cost Share Grace Period").[55] If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.[56]
- Project Teams where domestic educational institutions, domestic nonprofits, small businesses, and/or FFRDCs perform greater than or equal to 80% of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.
- Projects that do not meet any of the above criteria are subject to the base cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

4. LEGAL RESPONSIBILITY

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

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

[55] Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards). Applicants that are small businesses will be required to certify in the Business Assurances & Disclosures Form that their organization meets the SBA's definition of a small business under at least one NAICS code.

[56] See the information provided in previous footnote.

5. COST SHARE ALLOCATION

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

6. COST SHARE TYPES AND ALLOWABILITY

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

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

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

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

In addition, Project Teams may not use independent research and development (IR&D) funds[57] to meet their cost share obligations under Cooperative Agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under "other transaction" agreements.

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

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

[57] As defined in Federal Acquisition Regulation SubSection 31.205-18.

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

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

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

8. COST SHARE VERIFICATION

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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

Full Applications are deemed compliant if:

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

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

Replies to Reviewer Comments are deemed compliant if:

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

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

2. RESPONSIVENESS CRITERIA

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

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.

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

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

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

- Solutions that rely on revenue from CO_2 sold for enhanced oil recovery.
- Solutions that rely on revenue from solids, liquids, or gases produced as a byproduct of the CCS plant.
- Solutions that rely on revenue from CO2 sold for chemical or fuel synthesis.
- Solutions that rely on hydrogen production at volumes that cannot be accommodated with existing combustion systems (gas turbines and internal combustion engines) and natural gas pipeline infrastructure.

4. LIMITATION ON NUMBER OF SUBMISSIONS

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

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

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

2. CONCEPT PAPERS

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

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Concept Papers found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria and program policy factors in Sections V.A.1 and V.B.1 of the FOA.

ARPA-E will encourage a subset of Applicants to submit Full Applications. Other Applicants will be discouraged from submitting a Full Application in order to save them the time and expense of preparing an application submission that is unlikely to be selected for award negotiations. By discouraging the submission of a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. Unsuccessful Applicants should continue to submit innovative ideas and concepts to future FOAs.

3. FULL APPLICATIONS

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

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive, as described in Section III.C of the FOA. Full Applications found to be noncompliant or nonresponsive may not be merit reviewed or considered for award. ARPA-E makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA.

4. REPLY TO REVIEWER COMMENTS

Once ARPA-E has completed its review of Full Applications, reviewer comments on compliant and responsive Full Applications are made available to Applicants via ARPA-E eXCHANGE. Applicants may submit an optional Reply to Reviewer Comments, which must be submitted by the deadline stated in the FOA. Section IV.E of the FOA provides instructions on submitting a Reply to Reviewer Comments.

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

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

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

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

6. SELECTION FOR AWARD NEGOTIATIONS

ARPA-E carefully considers all of the information obtained through the application process and makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA. The Selection Official may select all or part of a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

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

B. APPLICATION FORMS

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

C. CONTENT AND FORM OF CONCEPT PAPERS

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

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

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

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

A fillable Concept Paper template is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

Concept Papers must conform to the content requirements described below. If Applicants exceed the maximum page length indicated above, ARPA-E will review only the authorized number of pages and disregard any additional pages.

1. CONCEPT PAPER

a. CONCEPT SUMMARY

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

b. INNOVATION AND IMPACT

- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Provide the information requested in the table below, as defined (and described in further detail) in Section I.D. of the FOA:

Attribute	SOA Value	Proposed Value	Description / Justification
Power generator type	n/a	n/a	
CCS plant technology	n/a	n/a	
Capital cost			
Fixed O&M cost			
Variable O&M cost			
Power generator heat rate			
Flexibility enabler	n/a	n/a	
Capture rate			

c. PROPOSED WORK

- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives.
- Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach. Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.
- For Applicants proposing a detailed budget and tasks for Phase 1 and Phase 2: Provide the information requested in the table below, as defined and described in Section I.D. of the FOA:

Cost or performance risk	Novelty of proposed approach	Experimental strategy to reduce cost and performance risk
[Risk #1]		
[Risk #2]		
[Applicants to decide how many risks to include]		

d. TEAM ORGANIZATION AND CAPABILITIES

- Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.
- Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.
- Provide the information requested in the table below, as defined (and described in further detail) in Section I.D. of the FOA

Subject matter expertise	Team member(s) responsible	Description / Justification
CCS technology		
Process modeling		
Economic analysis		
Optimization		
Power generation (if applicable)		

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

F. INTERGOVERNMENTAL REVIEW

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

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

H. OTHER SUBMISSION REQUIREMENTS

1. USE OF ARPA-E eXCHANGE

To apply to this FOA, Applicants must register with ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/login.aspx). ARPA-E will not review or consider applications submitted through other means (e.g., fax, hand delivery, email, postal mail). For detailed guidance on using ARPA-E eXCHANGE, please refer to the "ARPA-E eXCHANGE Applicant Guide" (https://arpa-e-foa.energy.gov/Manuals.aspx).

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

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

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

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

ARPA-E may not review or consider incomplete applications and applications received after the deadline stated in the FOA. Such applications may be deemed noncompliant (see Section III.C.1 of the FOA). The following errors could cause an application to be deemed "incomplete" and thus noncompliant:

- Failing to comply with the form and content requirements in Section IV of the FOA;
- Failing to enter required information in ARPA-E eXCHANGE;

- Failing to upload required document(s) to ARPA-E eXCHANGE;
- Failing to click the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA;
- Uploading the wrong document(s) or application(s) to ARPA-E eXCHANGE; and
- Uploading the same document twice, but labeling it as different documents. (In the latter scenario, the Applicant failed to submit a required document.)

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

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

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

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

1. CRITERIA FOR CONCEPT PAPERS

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

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

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

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

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement. The above criteria will be weighted as follows:

Impact of the Proposed Technology Relative to FOA Targets	50%
Overall Scientific and Technical Merit	50%

2. CRITERIA FOR FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

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

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

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

III. **Synergy of Public and Private Efforts**.
   a. Avoids duplication and overlap with other publicly or privately funded projects;

b. Promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer; or
c. Increases unique research collaborations.

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

V. **High-Leveraging of Federal Funds**. Project leverages Federal funds to optimize advancement of programmatic goals by proposing cost share above the required minimum or otherwise accessing scarce or unique resources.

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

2. ARPA-E Reviewers

By submitting an application to ARPA-E, Applicants consent to ARPA-E's use of Federal employees, contractors, and experts from educational institutions, nonprofits, industry, and governmental and intergovernmental entities as reviewers. ARPA-E selects reviewers based on their knowledge and understanding of the relevant field and application, their experience and skills, and their ability to provide constructive feedback on applications.

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

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

3. ARPA-E Support Contractor

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

By submitting an application to ARPA-E, Applicants represent that they are not performing support contractor services for ARPA-E in any capacity and did not obtain the assistance of

ARPA-E's support contractor to prepare the application. ARPA-E will not consider any applications that are submitted by or prepared with the assistance of its support contractors.

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

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

2. CONCEPT PAPER NOTIFICATIONS

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

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

A notification letter encouraging the submission of a Full Application does not authorize the Applicant to commence performance of the project. Please refer to Section IV.G of the FOA for guidance on pre-award costs.

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2020]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

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

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

- ARPA-E will post responses on a weekly basis to any questions that are received that have not already been addressed at the link above. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- ARPA-E will cease to accept questions approximately 10 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted approximately one business day in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- Responses are published in a document specific to this FOA under "CURRENT FUNDING OPPORTUNITIES – FAQS" on ARPA-E's website (http://arpa-e.energy.gov/faq).

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

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

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

B. DEBRIEFINGS

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

VIII. OTHER INFORMATION

A. TITLE TO SUBJECT INVENTIONS

Ownership of subject inventions is governed pursuant to the authorities listed below. Typically, either by operation of law or under the authority of a patent waiver, Prime Recipients and Subrecipients may elect to retain title to their subject inventions under ARPA-E funding agreements.

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions. If Prime Recipients/Subrecipients elect to retain title, they must file a patent application in a timely fashion, generally one year from election of title, though: a) extensions can be granted, and b) earlier filing is required for certain situations ("statutory bars," governed by 35 U.S.C. § 102) involving publication, sale, or public use of the subject invention.
- All other parties: The Federal Non-Nuclear Energy Research and Development Act of 1974, 42. U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below)*.
- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues "class patent waivers" under which large businesses and foreign entities that meet certain stated requirements, such as cost sharing of at least 20%, may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.
- GOGOs are subject to the requirements of 37 C.F.R. Part 501.
- Determination of Exceptional Circumstances (DEC): DOE has determined that exceptional circumstances exist that warrant the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to maximize the manufacture of technologies supported by ARPA-E awards in the United States. The DEC, including a right of appeal, is dated September 9, 2013 and is available at the following link: http://energy.gov/gc/downloads/determination-exceptional-circumstances-under-bayh-dole-act-energy-efficiency-renewable. Please see Section IV.D and VI.B for more information on U.S. Manufacturing Requirements.

B. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

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

1. GOVERNMENT USE LICENSE

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

2. MARCH-IN RIGHTS

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

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

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

C. RIGHTS IN TECHNICAL DATA

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

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.
- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be

protected from public disclosure for a reasonable time in order to allow for filing a patent application.

D. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

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

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

E. FOAS AND FOA MODIFICATIONS

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

F. OBLIGATION OF PUBLIC FUNDS

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

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

G. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

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

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

H. RETENTION OF SUBMISSIONS

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

I. MARKING OF CONFIDENTIAL INFORMATION

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

Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information 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 U.S.

Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

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

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

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

J. COMPLIANCE AUDIT REQUIREMENT

A prime recipient organized as a for-profit entity expending $750,000 or more of DOE funds in the entity's fiscal year (including funds expended as a Subrecipient) must have an annual compliance audit performed at the completion of its fiscal year. For additional information, refer to Subpart F of: (i) 2 C.F.R. Part 200, and (ii) 2 C.F.R. Part 910.

If an educational institution, non-profit organization, or state/local government is either a Prime Recipient or a Subrecipient, and has expended $750,000 or more of Federal funds in the entity's fiscal year, the entity must have an annual compliance audit performed at the completion of its fiscal year. For additional information refer to Subpart F of 2 C.F.R. Part 200.

IX. GLOSSARY

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

Application: The entire submission received by ARPA-E, including the Concept Paper, Full Application, and Reply to Reviewer Comments.

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

Cost Sharing: is the portion of project costs not paid by Federal funds (unless otherwise authorized by Federal statue). Refer to 2 C.F.R. § 200.29.

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

DOE: U.S. Department of Energy.

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

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

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

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

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

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

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing any of the research and development work under an ARPA-E funding agreement, whether or not costs of performing the research and development work are being reimbursed under any agreement.

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

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

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

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

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