FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

SYSTEMS FOR MONITORING AND ANALYTICS FOR RENEWABLE TRANSPORTATION FUELS FROM AGRICULTURAL RESOURCES AND MANAGEMENT (SMARTFARM)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0002250
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Funding Opportunity Announcement (FOA) Issue Date:	December 18, 2019
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, Friday, February 7, 2020
Submission Deadline for Concept Papers:	9:30 AM ET, Wednesday February 19, 2020
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:	August 2020
Total Amount to Be Awarded	Approximately $20 million, subject to the availability of appropriated funds to be shared between FOAs DE-FOA-0002250 and DE-FOA-0002251.
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).

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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 seven (7) pages in length and must include the following: ○ Concept Summary ○ Innovation and Impact ○ Operational Plan and System Cost (not to exceed 2 pages; 1 for written response and 1 for figures) ○ Risk Matrix ○ Proposed Work ○ Team Organization and Capabilities	Mandatory	IV.C	9:30 AM ET, Wednesday, February 19, 2020
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2020]	Mandatory	IV.D	9:30 AM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN APRIL 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

U.S. agriculture has the potential to produce ~5 Quadrillion Btu of energy in the form of biofuels,[2] and with new innovations throughout the biofuel supply chain, these fuels could become *carbon negative*.[3] Reaching this potential and achieving greater carbon reductions requires that feedstock producers adopt new technologies and management practices that simultaneously improve yield, drive down production associated emissions, and enhance carbon sequestration in soils. To facilitate the adoption of these new technologies and practices for improved carbon management, feedstock producers need incentives beyond yield. While

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

[2] Langholtz, M. H., B. J. Stokes, and L. M. Eaton. "2016 Billion-ton report: Advancing domestic resources for a thriving bioeconomy, Volume 1: Economic availability of feedstock." Oak Ridge National Laboratory, Oak Ridge, Tennessee, managed by UT-Battelle, LLC for the US Department of Energy 2016 (2016): 1-411.

[3] See DE-FOA-0001565: Rhizosphere Observations Optimizing Terrestrial Sequestration (ROOTS); DE-FOA-0001563: Renewable Energy to Fuels through Utilization of Energy-dense Liquids (REFUEL); DE-FOA-0001211: Transportation Energy Resources from Renewable Agriculture (TERRA); DE-FOA-0000470: Plants Engineered To Replace Oil (PETRO)

carbon management incentive structures exist elsewhere in the biofuel supply chain, they do not extend to feedstock production because monitoring and verification of feedstock production emissions is too costly to conduct at the field level. Instead, all feedstock producers are assumed to produce the same amount of emissions— the national average —despite significant variations in actual emissions when moving to state or regional averages, let alone field-level estimates.[4]

The objective of the Systems for Monitoring and Analytics for Renewable Transportation Fuels from Agricultural Resources and Management (SMARTFARM) program is to bridge the data gap in the biofuel supply chain by funding the development of technologies that can replace national averages and emissions factors for feedstock-related emissions with field-level estimates. The value of such technologies will be evaluated by their ability to **reliably, accurately (i.e. low uncertainty), and cost-effectively quantify feedstock production lifecycle emissions (in g CO_2e/acre) at the field level (i.e. scalable to >80 acres).** If successful, the technologies funded by this phase of the SMARTFARM program will catalyze new market incentives for efficiency in feedstock production and carbon management, reducing annual U.S. emissions by ~1%,[5] and with substantially greater potential emissions reductions implications if expanded to other agricultural products beyond biofuels.

The SMARTFARM portfolio is structured in two initial phases: Phase 1 of the program, which is described in Topic H: Establishing validation sites for field-level emissions quantification of agricultural bioenergy feedstock production, of DE-FOA-0001953,[6] aims to support the establishment of high-resolution datasets that will be available to the public, without restriction, to support testing and validation of emerging monitoring technologies. These Phase 1 production sites will be outfitted with state-of-the-art equipment and monitored on a per-acre basis. The low profit margins of feedstock production[7] and high cost of monitoring technologies make it cost-prohibitive to monitor impacts on a larger scale at such high resolution, which is why this second phase of the portfolio intends to fund technologies capable of delivering the same estimates, at or below specified uncertainty levels, at a cost capable of delivering a positive return on investment when field-level carbon emissions reductions are connected to associated biofuel carbon markets. Under the SMARTFARM portfolio, Phase 2 technologies will be subject to rigorous testing to demonstrate performance in relevant

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[4] Liu, Xinyu, Kwon, Hoyoung, and Wang, Michael. GREET® Analysis for TERRA/ROOTS Success Scenarios. United States: N. p., 2019. Web. doi:10.2172/1546782

[5] Assuming a 30% reduction in nitrogen inputs and nitrous oxide emissions for corn-grain ethanol and ~100 kg/acre/year increase in soil carbon across the projected 5 Quadrillion Btu capacity for terrestrial biofuel feedstocks.

[6] DE-FOA-0001953: Solicitation on Topics Informing New Program Areas, Topic H: Establishing validation sites for field-level emissions quantification of agricultural bioenergy feedstock production

[7] USDA Economic Research Service. Corn production costs and returns per planted acre, excluding Government payments. For the base survey of 2016, the U.S. average for net value of production less overhead and operating costs ranged from -$45 to -$75 per acre.

deployment scenarios. Successful projects in this second phase of the portfolio will be encouraged to partner with Phase 1 site managers to deploy and validate their technologies.

C. PROGRAM OBJECTIVES

1. BACKGROUND:

In 2018, over 15 billion gallons of ethanol biofuel and 3.8 billion gallons of biomass-based diesel were generated and used in the transportation sector, amounting to ~1% of domestic energy demand.[8] In addition to being a strategic energy asset in the U.S., biofuels provide an economic growth benefit to the nation's farmers and deliver a net reduction in emissions associated with transportation fuels.[9] This reduction is primarily the product of market forces implemented through the Low-Carbon Fuel Standard (LCFS) and similar programs, which have driven cuts to biorefinery emissions[10] and incentivized continued evaluation of how to draw down emissions throughout the biofuel supply chain.

Looking forward, analysis suggests that crop-based biofuels have the potential to supply up to ~5% of U.S. energy demand,[2] and the benefit of this resource to the broader economy and environment could be substantially improved by making the biofuel supply chain carbon negative– i.e. the biofuel lifecycle removes and sequesters more carbon than it emits. While the carbon-negative potential of biofuel production is being investigated and pursued across the supply chain, an effort largely motivated by markets like the LCFS, reaching this potential will require detailed accounting of the inputs (e.g. energy, nutrients, chemicals) and outputs (e.g. energy, co-products, emissions) of the biofuel lifecycle in order to establish a reliable baseline against which to measure progress.

Emissions for the biofuel supply chain are quantified with LifeCycle Analysis (LCA), the tools of which typically model the full bioenergy pathway (Figure 1), including manufacturing of farm inputs, feedstock production and associated land-use change (LUC), biorefinery operations, and combustion, to calculate the amount of greenhouse gas emissions (GHGs) emitted per unit of biofuel produced and consumed (i.e. the carbon intensity or CI, in grams of carbon dioxide equivalent per megajoule, or CO_2e/MJ). In the case of the LCFS, analysis using the Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) model provides a

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[8] Department of Energy, Office of Energy Efficiency & Renewable Energy's Alternative Fuels Data Center.

[9] Lewandrowski, Jan, et al. "The greenhouse gas benefits of corn ethanol–assessing recent evidence." Biofuels (2019): 1-15.

[10] Between 25% and 40% emissions reduction, based on emissions intensity values for processing in 2009 and 2018 - See California Air and Resources Board's Detailed California-Modified GREET Pathway for Corn Ethanol. (Version 2.0 Released January 20, 2009), and J. Rosenfeld, J. Lewandrowski, T. Hendrickson, K. Jaglo, K. Moffroid, and D. Pape, 2018. A Life-Cycle Analysis of the Greenhouse Gas Emissions from Corn-Based Ethanol. Report prepared by ICF under USDA Contract No. AG-3142-D-17-0161. September 5, 2018.

complete LCA of transportation fuels including gasoline and ethanol derived from multiple different feedstocks.[11]

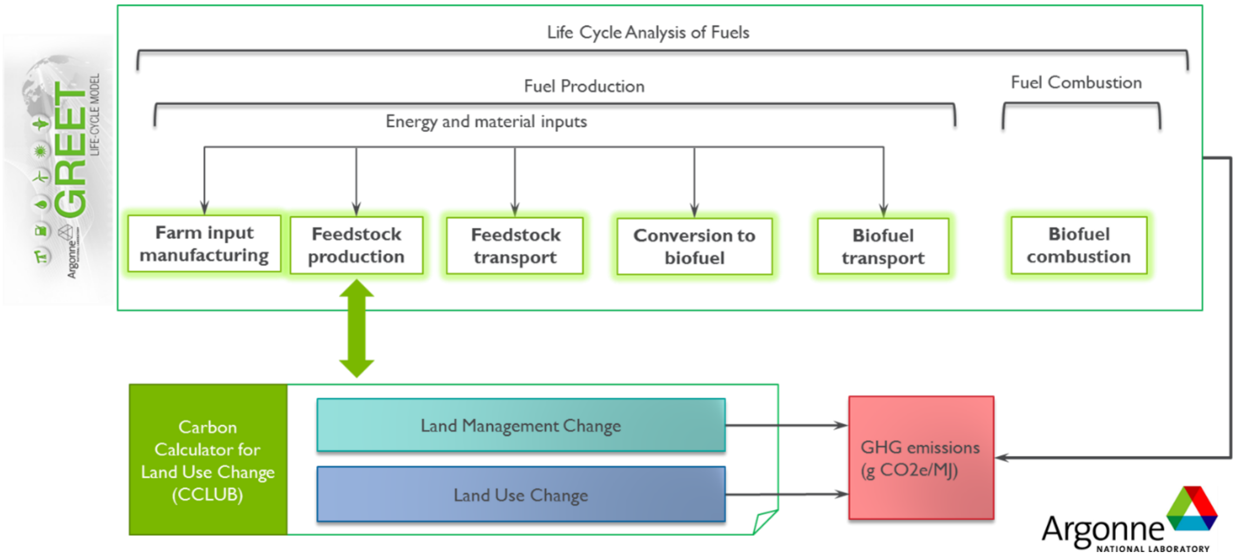

Figure 1 System boundary of biofuel LCA[12]

Currently, LCA of ethanol production estimates that ~40% of emissions are contributed by the feedstock production and input manufacturing stages. Variations in environment and management practices produce a broad range of yield outcomes and associated emissions, which get lost in national averages.[4] As shown in Figure 2, much of the CI of biofuels— in this case, corn-based ethanol— is tied to nitrogen-use efficiency. Nitrogen fertilizer production (i.e. "N Applied" in Figure 2) contributes ~20% of total feedstock emissions, while nitrous oxide (N_2O) emitted over the course of a season contributes ~50%. The remaining emissions associated with feedstock production are the product of energy use (e.g. fuel, ~10%), soil respiration in the form of CO_2 (i.e. soil carbon loss, ~10%), and the production of other chemical inputs (e.g. herbicides and pesticides, ~10%). In the case of soil respiration, the net loss or gain of soil carbon is largely dependent on management practices (e.g. tillage, residues, cover crops) both within and across seasons.

[11] See California Air Resources Board LCA Models and Documentation at https://ww3.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm
[12] Argonne National Laboratory (2019) "GREET Models." October 4, 2019. https://greet.es.anl.gov/greet.models

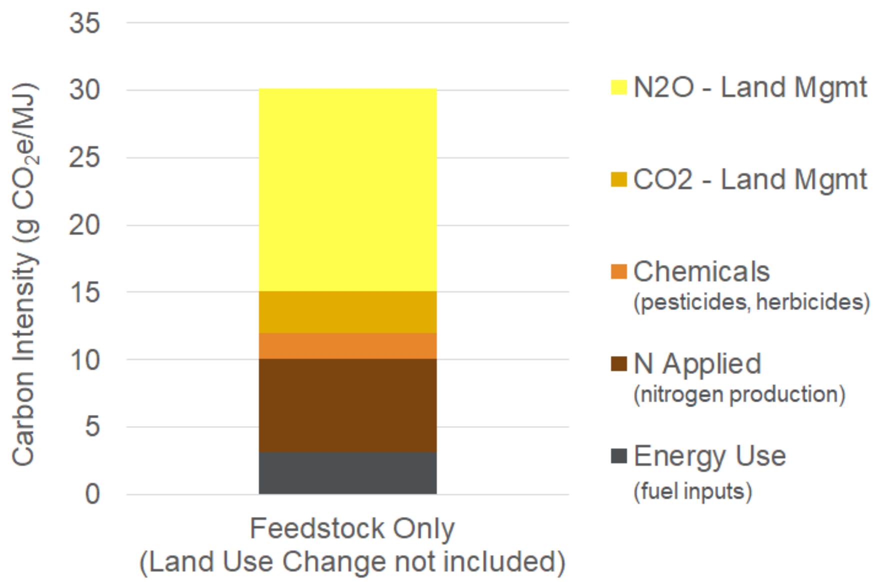

Figure 2 Typical feedstock production emissions breakdown. Emissions values vary by state and region.

Ultimately, positive emissions in the form of nitrogen loss as N_2O, and potentially negative emissions in the form of soil carbon, are the two primary drivers of a feedstock's CI. In most cases, there is significant room for improvement to both,[13,14,15] but current feedstock production practices are only compensated in terms of yield, and low profit margins leave feedstock growers with limited options for improving production efficiency (i.e. yield per unit input), let alone carbon efficiency (i.e. emissions per unit output). Instead, historically-high fertilizer rates that are driven by the primary focus on yield produce unnecessary emissions, impact water quality, and have uncertain returns (e.g. an estimated $267–702 million of fertilizer value is lost each year[15]). While these impacts are understood on a regional or national scale, field-level contributions remain unknown because of the variability mentioned previously, and the data are notoriously difficult to measure, both in terms of instrumentation and operational (e.g. sample collection, preparation and analysis) costs. **Therefore, systems for reliably and cost-effectively measuring seasonal N_2O emissions and annual soil carbon flux at the field level will be the focus of this phase of the SMARTFARM portfolio.** The highly reliable measurements from such instrumentation will provide sufficient confidence to carbon markets, allowing for producers to be properly compensated for the better carbon management practices they implement, instead of the "national average."

[13] Board, Ocean Studies, and National Academies of Sciences, Engineering, and Medicine. *Negative emissions technologies and reliable sequestration: a research agenda*. National Academies Press, 2019, USFRA
[14] U.S. Farmers & Ranchers Alliance. 2019. The Power of Resiliency in Agriculture's Ecosystem Services
[15] Basso, Bruno, et al. "Yield stability analysis reveals sources of large-scale nitrogen loss from the US Midwest." *Scientific reports* 9.1 (2019): 5774.

1.1 N_2O Emissions Monitoring:

Agricultural soil management (i.e. fertilizer application and other practices to increase nitrogen availability) is the primary contributor of N_2O emissions, which contribute ~4% of U.S. GHG emissions annually.[16] This contribution has a two-fold impact from an energy and emissions perspective: (1) production of synthetic nitrogen via Haber-Bosch is an energy- and emissions-intensive process, and (2) the loss of this nitrogen as N_2O, while estimated to be only 1-2% of nitrogen applied,[17] accounts for ~75% of total annual N_2O emissions in the U.S.[16] Furthermore, N_2O molecules are ~300X more powerful than CO_2 as a GHG,[18] and, unlike CO_2, terrestrial sinks for N_2O do not exist at a significant scale.[19] Despite the significant impact that N_2O emissions have, as well as the impact of their origin (i.e. loss of fertilizer and its embodied energy), there are many technical challenges associated with producing estimates for these emissions at the field level with low uncertainty. These challenges are described in detail in the literature and summarized below.

N_2O emissions are a function of management practices, soil properties, weather patterns, and multiple biological processes. Beyond the spatial variation in nutrient needs due to various biogeochemical properties, studies show year-to-year changes in optimum nitrogen can vary by a factor of two.[20,21] The high degree of spatial and temporal variation in nitrogen requirements makes it extremely difficult to optimize for nitrogen use efficiency, but there are multiple products at various stages of development that seek to help with nitrogen management in general. If carbon credits were to be paid for field-specific nitrogen management, it would help incentivize practices that reduce emissions associated with nitrogen production by optimizing the total amount of nitrogen applied.

From a carbon intensity perspective, solutions that specifically manage nitrogen losses as N_2O would impart the dual benefit of nitrogen efficiency (i.e. production efficiency) and carbon efficiency. The average loss in the GREET model associated with field-level N_2O is ~15 g CO_2e/MJ.[12] At a carbon price of $200/metric ton (MT), this loss is associated with a potential payment of ~$120/acre,[22] which could incentivize significant changes in farm management

[16] 266 million metric tons of CO_2e in the U.S. in 2017. See EPA. 2019. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017 (Chapter 5: Agriculture).
[17] Intergovernmental Panel on Climate Change (IPCC). 2006. IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K, eds. Agriculture, Forestry and Other Land Use 4: Hayama, Japan: IGES.
[18] See Environmental Protection Agency, Understanding Global Warming Potentials at https://www.epa.gov/ghgemissions/understanding-global-warming-potentials
[19] Paustian, Keith, et al. "Climate-smart soils." Nature 532.7597 (2016): 49-57.
[20] Scharf, Peter C., et al. "Field-scale variability in optimal nitrogen fertilizer rate for corn." Agronomy Journal 97.2 (2005): 452-461.
[21] Tremblay, Nicolas, et al. "Corn response to nitrogen is influenced by soil texture and weather." Agronomy Journal 104.6 (2012): 1658-1671.
[22] See California Air Resources Board's Data Dashboard for carbon credit prices, currently ~$200/MT (https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm). Other assumptions include average yield of 178 bushels per acre, 0.35 bushels of corn per gallon ethanol produced, and 80 MJ per gallon of ethanol.

practices. Since only a small portion of applied nitrogen is lost as N_2O, there are many reasons to believe there are opportunities to manage this form of nitrogen loss without reducing yield.

The loss of applied nitrogen in the form of N_2O is often dominated by a limited number of locations within a field and environmental conditions during specific periods of the year. If these 'hot spots' (characterized by topography, soil type, moisture, etc.) and 'hot moments' (characterized by fertilizer application, precipitation, temperature) are not properly monitored, measurements can produce estimates that undercount N_2O emissions by as much as 80%.[23] Current solutions to address the variability of N_2O emissions function on very different spatial and temporal scales and, in most cases, certainty increases as estimates are aggregated to a regional/national and annual level. Monitoring N_2O at different scales comes with trade-offs in terms of cost, complexity, and uncertainty, and the design of statistically valid systems for estimating N_2O losses is likely to require an integrated approach that combines process, field, and regional dynamics.

At the sub-meter scale, static and automatic chambers are the most widely used techniques for quantifying soil N_2O flux in the field. These devices are relatively inexpensive, easy to use, and allow a finer-scale study of different treatments and processes; however, coverage is limited and therefore does not sufficiently address spatial heterogeneity, and installation can introduce disturbances to soil, plants, and field operations. There is also a significant labor constraint, particularly for static chambers, limiting measurement intervals and potentially missing peak emissions periods. The use of automated chambers has addressed the labor constraint to some degree, but comes with additional costs that exacerbate spatial coverage challenges.

At the meter-to-kilometer scale, developments in fast-response Eddy Covariance analyzers for N_2O flux measurements have only recently become available and are still restricted to the research environment as they involve complex and expensive instrumentation, highly technical support staff, and frequent maintenance and calibration. Eddy Covariance relies on near-continuous and highly accurate measurements of gas concentrations and air movements, which can be used to estimate net gas exchange between soils and the atmosphere at the ecosystem level; however, estimation requires substantial and complex computation and still relies on certain assumptions regarding the homogeneity and topography of study plots.[24,25]

Modeling approaches offer a supplement to direct N_2O measurements and range in terms of scale and complexity, from emissions-factor approaches (e.g. IPCC) for regional estimates to detailed biogeochemical modeling (e.g. Denitrification-Decomposition (DNDC); daily time-step version of the CENTURY biogeochemical model (DayCENT)) of specific environments. Emissions factors such as those used by the Intergovernmental Panel on Climate Change (IPCC) are

[23] McGowan, Andrew R., Kraig L. Roozeboom, and Charles W. Rice. "Nitrous oxide emissions from annual and perennial biofuel cropping systems." Agronomy Journal 111.1 (2019): 84-92.
[24] Butterbach-Bahl, Klaus, et al. "Nitrous oxide emissions from soils: how well do we understand the processes and their controls?." Philosophical Transactions of the Royal Society B: Biological Sciences 368.1621 (2013): 20130122.
[25] A detailed overview of the state of the art in eddy measurement of N_2O can be found in Nemitz, Eiko, et al. "Standardisation of eddy-covariance flux measurements of methane and nitrous oxide." International agrophysics 32.4 (2018): 517-549.

straightforward to use and work well at the continental and global scales for the purpose of estimating N_2O emissions associated with land management practices, but they are unable to capture the complex exchange at smaller spatial scales. Over the last several years, numerous process-based models have been developed to capture the nitrogen cycle in greater detail; these models vary in terms of data input and model complexity when it comes to the description of nitrogen turnover (e.g. mineralization, nitrification, and denitrification) and N_2O production (Figure 4). Setting aside the exact processes captured by what Butterbach-Bahl et al refers to as the (a) simplified, (b) conceptual, and (C) complex model pathways shown in Figure 3, it is easy to imagine how a model's computational demand and both parametric and structural uncertainty increase with model complexity.[24] Additionally, capturing and incorporating field-specific datasets (e.g. soil pH and moisture field maps at high resolution) to improve modeling at the field level is still difficult to do at scale.[26]

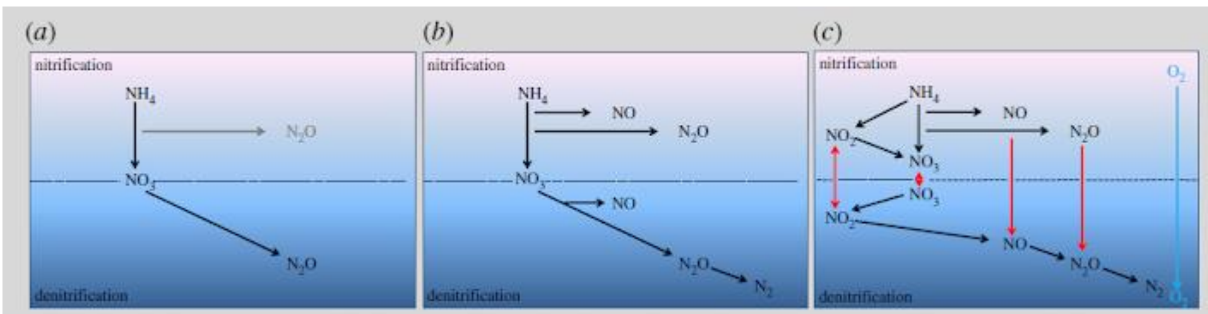

Figure 3 Varying levels of process detail included in (a) simplified, (b) conceptual, and (C) complex models as described by Butterbach-Bahl et al.[24] A more detailed description of the processes captured by these models can be found in the paper and documentation for individual models.

The summary above only scratches the surface of a significant body of work dedicated to monitoring and improving nitrogen use efficiency. The three N_2O quantification approaches outlined— chamber, Eddy Covariance, and modeling techniques —are the most widely used; however, how these techniques are applied, combined, and supplemented, varies widely, as does the success rate. With regard to this Funding Opportunity Announcement, submissions, whether inventing a new sensing modality, utilizing existing sensing modalities in new ways, or utilizing some combination of in-field sensing, remote sensing, and modeling, will all be evaluated in terms of cost, operational complexity and certainty. For example, a combination of soil, input, and yield mapping; imagery from satellites, UAVs, airplanes, etc.; and a select number of "smart" measurements utilizing the revolution in cheap and reliable distributed wireless sensing (e.g. right time and place, in situ/continuous) could produce high-resolution estimates with much lower uncertainty while limiting the cost and physical footprint of monitoring. When considering how to accurately monitor N_2O at a field level, challenges to be addressed include:

[26] ARPA-E 2018 Workshop: The Energy-Smart Farm: Distributed Intelligence Networks for Highly Variable and Resource Constrained Crop Production Environments. https://arpa-e.energy.gov/?q=workshop/energy-smart-farm-distributed-intelligence-networks-highly-variable-and-resource

- Determination of which measurements (e.g. N_2O, soil moisture, temperature) are necessary
- When, where, and how the measurements should be taken such that they capture the necessary data without disruption to field operations
- When and how the in-field data will be combined with other data layers and what statistical analyses will be applied
- How uncertainty will be managed and reduced; relatedly, how the system will minimize if not eliminate data gaps during the critical season[27]
- How all of the above will be made operationally efficient, with positive economics, at scale

As illustrated by the list above, the N_2O monitoring challenge is a complex one— each of the bullets above comes with its own technical challenges, which are compounded by environmental heterogeneity, operational and financial limitations, and assurance of data quality and origin. Successfully addressing these challenges would mean immediate market relevance in clean fuel markets, nitrogen efficiency R&D environments (e.g. nitrogen inhibitor providers, EPA, USDA), and the broader agricultural sector, which contributes ~3% of annual U.S. emissions in the form of N_2O from cropland soils.[16]

1.2 Soil Carbon:

In addition to increasing awareness of the role that soils play in critical ecosystem services—e.g. crop production, nutrient cycling, water —the carbon sequestration potential of soils has garnered much attention over the last several years and offers a near-term and potentially low-cost and large-scale carbon drawdown opportunity.[13] Soils constitute the largest terrestrial organic carbon pool, with the equivalent of 3X the amount of CO_2 in the atmosphere stored within the top 2 meters; analysis suggests that up to 60% of U.S. transportation emissions could be sequestered annually.[28]

There are numerous accounts of the environmental and economic benefits of improved soil health, and, conversely, the consequences of depleted soils.[13,14,29] The fact that soil carbon optimization strategies, which directly contribute to overall soil health, have not been widely adopted despite these benefits points to a need for economic incentives to offset the potential risks and/or costs associated with carbon optimization. Presently, the only markets for soil carbon are voluntary, and incentives from these markets are an order of magnitude lower than those of regulated markets such as the LCFS, typically <$20/ metric ton of carbon sequestered. As a result, these voluntary markets must rely on low-resolution and high-uncertainty techniques for quantifying soil carbon or risk declines in participation. Mandating more precise

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[27] Here, the “critical season” is defined as the period beginning at soil thaw and lasting through the month after the last nitrogen application.

[28] DE-FOA-0001565: Rhizosphere Observations Optimizing Terrestrial Sequestration (ROOTS), based on analysis by Paustian, Keith, et al. *Assessment of potential greenhouse gas mitigation from changes to crop root mass and architecture*. Booz Allen Hamilton Inc., McLean, VA (United States), 2016.

[29] Doane, M., and M. Doane. "reThink Soil: A Roadmap for US Soil Health." The Nature Conservancy (2016).

measurement of soil carbon introduces a tension between the cost of quantification and the revenue potential, both of which are inversely proportional to uncertainty[30] introduced by the high spatial variability of soils and the small changes in carbon relative to the "background" stock.[31]

Thus, in contrast to nitrogen-based emissions reductions, which are quantified on a yield or MJ basis and can therefore impart annual payments to growers, soil carbon flux monitoring occurs over longer time scales, typically 5-10 years, in order to detect statistically significant soil carbon stock changes with moderate sampling density. Still, technical challenges related to sampling strategy and measurement technique persist and ultimately limit the market potential for soil carbon storage as uncertainty throttles revenue potential and market participation.[30] These challenges are described in detail in the literature and summarized below.

1.2.1 Soil Carbon – Sampling:

The high degree of spatial variation, even in what appear to be "uniform" fields, means that soil carbon content can vary by as much as 5X within the same field; carbon content also changes with depth, with the highest concentrations in the top 20-30 cm of soil. For this reason, appropriate sample number, location, and depth will depend on the management practices and soil type/profile being evaluated, with conventional randomized sampling approaches requiring hundreds of samples in order to obtain an accurate estimation of the "average" soil carbon content of a multi-acre field.[32,33]

The most widely used soil carbon sampling strategies are design- and model-based, with the randomness of an observation originating from the random selection of sample sites for design-based methods, and from the random term introduced in the model of spatial variation for model-based methods. Deciding which of these approaches to use, and how well they will work, will depend on the purpose; for example, a 2016 evaluation[33] of design-based, model-assisted, and model-based sampling and estimation found that, while estimates were similar, model-based estimates had smaller variances than those of design-based methods. While this result represents an advantage of model-based methods in terms of reducing uncertainty, a disadvantage of this approach is that results are not generalizable to other sampling designs. Addressing this disadvantage to achieve a commercially relevant solution risks increasing uncertainty as the model becomes more general, or increasing cost as model calibration requirements mount for site-specific estimates.

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[30] A more detailed discussion can be found in *Uncertainty Impact on Carbon Credits* below.

[31] Paustian, Keith, et al. "Quantifying carbon for agricultural soil management: from the current status toward a global soil information system." *Carbon Management* 10.6 (2019): 567-587.

[32] England, J., and Raphael Viscarra Rossel. "Proximal sensing for soil carbon accounting." Soil 4.2 (2018): 101-122.

[33] Rossel, RA Viscarra, et al. "Baseline estimates of soil organic carbon by proximal sensing: Comparing design-based, model-assisted and model-based inference." Geoderma 265 (2016): 152-163.

A more detailed discussion of sampling strategies, associated advantages and disadvantages, and cost/uncertainty trade-offs, can be found in the literature. [31,34,35] Regardless of the sampling strategy, it is important that sampling be sequential in order to enable statistically significant differences to be revealed; however, even with a thoughtful sampling plan, it is not as simple as picking samples from the same area each year and comparing them against each other. When considering market structures and loopholes, annual random sampling provides greater confidence that whole-field management strategies are being applied (vs. carefully tending to certain areas that are known to be measured).

1.2.2 Soil Carbon - Measurement

The optimal sampling strategy will also depend on the method of measurement, with most options falling into one of three categories: conventional (i.e. lab-based) analysis, advanced sensing, and modeling that may or may not use direct measurements as inputs (e.g. remote imagery could be used instead of direct measurements[36]).

In all cases, effectively accounting for soil carbon stocks (C_s in Equation 1) and changes requires a combination of measurements, with primary inputs being soil carbon concentration (C_m, in %), bulk density (ρ, in g/cm^3), gravel content (g , in %), and depth (d, in cm).[37] These measurements produce an estimate of the mass of carbon per unit area, typically in metric tons per hectare or acre, using the following equation:

$$C_s = C_m \; x \; \rho \; x \left(1 - \frac{g}{100}\right) x \; d \qquad (\textit{Equation 1})$$

Conventional analysis requires that volumetric samples be collected, dried, crushed, and sieved before analysis via automated dry combustion. This is an expensive and laborious process, but it is currently the “gold standard” in soil science research; in non-R&D environments, the cost and labor associated with this form of measurement significantly lowers the number of samples taken, resulting in estimates with high uncertainty. Furthermore, these methods of analysis are destructive in nature, as determining the carbon content as a percent of soil mass requires homogenization, grinding, etc., and bulk density measurement requires known volumes and standard conditions for weighing. Collection, transport, and processing add time and cost to an already burdensome process.

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[34] Heuvelink, G. B. M., et al. "Towards a sampling design for monitoring global soil organic carbon stocks." Book of Abstracts Wageningen Soil Conference 2017. 2017.
[35] Viscarra Rossel, Raphael A., and Dick J. Brus. "The cost-efficiency and reliability of two methods for soil organic C accounting." Land degradation & development 29.3 (2018): 506-520.
[36] Angelopoulou, Theodora, et al. "Remote sensing techniques for soil organic carbon estimation: A review." Remote Sensing 11.6 (2019): 676.
[37] England, J., and Raphael Viscarra Rossel. "Proximal sensing for soil carbon accounting." Soil 4.2 (2018): 101-122.

Advanced measurement methods such as spectroscopic techniques (e.g. visible-near-infrared and mid-infrared diffuse reflectance spectroscopy) can be used in the lab or the field, and have the potential to deliver rapid, cheap analysis. While these methods have faster throughput when compared to combustion methods, speed comes at the cost of accuracy, and results must be carefully calibrated for different geographic areas and soil types.[37] Other methods (e.g. laser-induced breakdown spectroscopy, diffuse reflectance Fourier transform infrared spectroscopy, inelastic neutron scattering) have been tested, but none have yet emerged as a viable replacement for conventional analysis methods. Looking forward, a more ambitious goal is to develop "on-the-go" sensors that can be drawn by tractors or dedicated equipment. This approach is still in the early stages and requires calibration and measurement of bulk density.[31]

Modeling approaches include empirical and process-based models, both of which are based on data from long-term field experiments. Empirical models are based on statistical relationships and are therefore restricted to inferences based on the observations used to build the model. For example, IPCC GHG inventory guidelines provide an easy method of estimating national-scale soil carbon stock changes as a function of land use management practices; this method is based on soil sample measurements, although the data do not necessarily cover all soil types, climates, management combinations, etc. Process-based models are based on scientific understanding and tend to aim to achieve more of a general understanding and/or predictive capability based on soil carbon dynamics. Process-based models are more suitable for extrapolation and representation of environments and conditions that are underrepresented in observed data and generally take the form of simulations, most of which were developed for research purposes. There are several process-based models that include soil carbon, and in some cases, both N_2O emissions and soil carbon can be estimated using the same model; DAYCENT, for example, is being used for soil carbon changes and emissions of N_2O and CH_4 in the U.S. GHG inventory and reporting system. Hybrid approaches are also available; for example, COMET-Farm is a web-based full GHG accounting decision support system that employs empirical models for certain GHG sources and process-based models for soil carbon stock changes and N_2O emissions.[31]

The content above is only a summary of a significant body of work dedicated to the quantification and monitoring of soil carbon stocks, and in mentioning them, ARPA-E is not intending to endorse any particular method or approach. The three quantification approaches outlined— conventional, advanced, and modeling techniques —are the most widely used; however, how these techniques are applied, combined, and supplemented, varies widely, as does the success rate. Similar to N_2O monitoring approaches, it is likely that some combination of in-field and/or remote sensing and modeling will be required to maintain a balance between cost, complexity and certainty; however, a key difference between the approaches to quantifying these two emissions drivers is the time scale involved. Whereas N_2O estimates require frequent— if not continuous —monitoring, soil carbon measurement need only occur on an annual basis given the small annual changes in soil carbon relative to background stocks. Spatial heterogeneity remains a challenge, however, both in terms of area and depth, which introduces a trade-off of coverage (and therefore uncertainty) and cost. Compounding this challenge is the destructive and invasive nature of current tools (e.g. digging pits, taking soil cores, and hauling associated equipment in and out of the field), which not only limits the area covered but also the timeframe in which samples can be collected. There is only a short window between harvest and winter weather (e.g. mud and snow, which can make it near impossible to transport the kinds of equipment required to get to desired depths), and much area to cover during that time if carbon measurements were to be captured at scale with high certainty. Tools capable of delivering value in future carbon markets must consider:

- Which measurements (e.g. field-based or remote, lab analysis) are necessary
- Where and how the measurements should be taken such that they capture spatial heterogeneity— both in area and depth —without disruption to field operations
- When and how they will be combined with other data layers, and what statistical analyses will be applied
- How uncertainty will be managed and reduced
- How all of the above will be operationally efficient, with positive economics, at scale

As illustrated by the list above, the soil carbon monitoring challenge is a complex one— each of the bullets above comes with its own technical challenges, which are compounded by environmental variability, operational and financial limitations, and assurance of data quality and origin. Successfully addressing these challenges would mean immediate market relevance in existing carbon markets, R&D environments (e.g. USDA), and the broader agricultural sector.

1.3 Uncertainty Impact on Carbon Credits:

Both agricultural feedstock producers and industrial biofuel refiners are seeking to improve the CI attributes of biofuel feedstocks but are lacking the tools to do so; the discussion above highlights some of the major technology gaps in today's measurement and estimation methods. Meanwhile, market structures aimed at incentivizing carbon efficiency in biofuel markets (e.g. LCFS) and in agriculture more broadly (e.g. USDA Environmental Quality Incentives Program and Conservation Stewardship Program initiatives, and other voluntary markets like the Verified Carbon Standard and American Carbon Registry) are limited to low-resolution and high-uncertainty estimates of feedstock production emissions.

Moving to project-based certification introduces uncertainty in emissions impact due to sampling errors, sensor variation, and model uncertainty. If payments are based on these measured values, they will need to incorporate this uncertainty to ensure that the incentivized impact is not overstated and the effort is not over- or under-compensated. If the error is random, uncertainty decreases with the size of the project, and bundled projects can be used to generate value; however, this is an undesirable state because lowering the resolution of credit values reduces individual incentive and there limits the incentive for individual practice innovation.[38] In current markets, measurement at individual sites can be discounted in direct proportion to the uncertainty of the emission measurement (e.g. credits can be valued on the

[38] Applied Geosolutions. DNDC Model Validation and Quantification of Structural Uncertainty to Support Rice Methane Offset Protocols. https://www.c-agg.org/wp-content/uploads/Salas-CSU-C-AGG_mtg_DNDC_rice_uncertainty.pdf

10th percentile).[39] The standard deviation of a measurement system can be used to discount the value of credits generated.

Putting this into real numbers (see Figure 4 below) – if a field that reduces emissions from a national average of 30 g CO_2e/MJ to 15 g CO_2e/MJ is measured with three different systems that have a standard deviation (SD) of 1, 3, and 10 g CO_2e/MJ, adjusting the value to the 90th percentile would result in a credit of approximately 16, 20, and 28 g CO_2e/MJ. In this example, three example systems measure an accurate value of 15 gCO_2e / MJ with increasing SD. The project emissions can be credited at the 90th percentile (CI Value + ~1.3SD), meaning there is 90% certainty that local emissions are lower than this value. Because of discounting to improve certainty, the SD determines the economic value of the credits and the worth of a monitoring system.

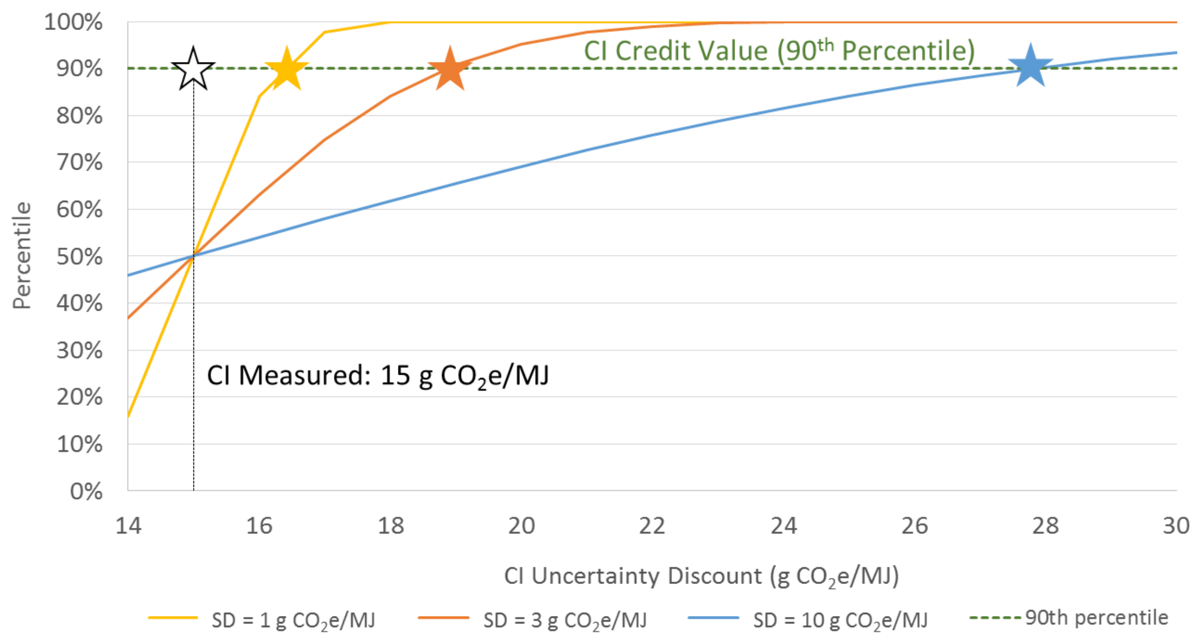

Figure 4 Three example systems measure a CI value of 15 gCO_2e / MJ ("CI Measured" above) with increasing SD. The project emissions can be credited at the 90th percentile ("CI Credit Value" = CI + ~1.3SD), meaning there is 90% certainty that local emissions are lower than this value. In other words, if we assume a baseline of 30 g CO_2e/MJ and a measured CI of 15 g CO_2e/MJ, the credit for the 15 g reduction would be adjusted (i.e. discounted) to a 14, 10, or 2 g CO_2e/MJ based on the SD of 1,3, and 10 g CO_2e/MJ, respectively.

[39] Kim, Man-Keun, and Bruce A. McCarl. "Uncertainty discounting for land-based carbon sequestration." Journal of Agricultural and Applied Economics 41.1 (2009): 1-11.

Table 1 Using the three example systems in Figure 4, the measured CI of 15 g CO_2e/MJ is adjusted upwards based on the degree of uncertainty (i.e. the SD), which thereby reduces the CI reduction that a feedstock producer would be paid for. For the SD = 10 measurement system, the measured CI of 15 g CO_2e/MJ gets adjusted to 28 g CO_2e/MJ, which, for a baseline of 30 g CO_2e/MJ, means the producer would only get paid for a 2 g CO_2e/MJ reduction. The estimates below are for illustrative purposes and assume average per-acre yields of ~180 bushels, or ~41,000 MJ produced per acre.

CI Credit	CI Reduction (90% certainty)	Per-acre Credit (30 g baseline)	Per-acre Payment ($200/MT carbon)
☆ **15 g**	15	615,000	$123
★ **16 g (SD = 1)**	14	574,000	$112
★ **20 g (SD = 3)**	10	410,000	$83
★ **28 g (SD = 10)**	2	82,000	$16

As shown in Figure 4 and Table 1, reducing the uncertainty of emissions quantification is critical to realizing the revenue potential of carbon management markets. Doing so successfully means that solutions must balance a complex trade-off between the cost and complexity of measurement, the uncertainty associated with the final output (i.e. g CO_2e/MJ), and the revenue potential of obtaining such granular information.

Thus far, economic forces have hindered adoption of advanced technology for commodity production, and high-resolution (i.e. field-level) data is lacking as there is much to be understood about monitoring such varied and complex environments and dynamics. However, the technological revolution and digitization of the U.S. farm is already underway. ARPA-E's TERRA and ROOTS programs have funded dramatic advances in sensing, imaging, robotics, genetics, and computing technologies, and new developments in sensor engineering and identity preservation developed for medical and security purposes are primed for adaption to agricultural production systems to create new monitoring and decision support systems.

Enabling producers to participate in carbon management markets would complement yield-based revenues with economic incentives for input efficiency and restorative practices, while laying the groundwork for other market structures to shift away from national and regional averages toward field-based estimates. While initially applying to existing markets, which could extend to biomass crop feedstocks, these tools could also be applied to production agriculture more broadly to improve its energy balance. The agricultural industry as a whole is a significant contributor of both energy usage and emissions, representing ~2% of U.S. energy use,[40] and ~8% of U.S. emissions.[16]

[40] USDA ERS. Energy Consumption and Production in Agriculture. 2014.

D. TECHNICAL CATEGORIES OF INTEREST

ARPA-E requests submissions for Phase 2 technology solutions capable of producing effective quantification of feedstock-related N_2O emissions (Category 1) or soil carbon storage (Category 2) at the field level. ARPA-E anticipates such quantification will require a "system of systems" to include, but not be limited to, in-field sensors, UAV and satellite imagery, agronomic data, and modeling/simulation tools. Submissions for direct and indirect measurement of the key carbon intensity drivers (i.e. N_2O and soil carbon) are encouraged. Systems must be described in terms of:

- Sensing modality/modalities applied, along with their power source, communication source, any onboard computation hardware, and packaging
- System deployment, calibration, cost, and lifetime
- Communication between modalities (where applicable)
- Data fusion, statistical analysis, models, etc., to be used to produce the key output of either N_2O (g CO_2e/acre) or soil carbon (metric tons of carbon per acre (MT C/acre))
- How uncertainty will be managed and estimated

E. TECHNICAL PERFORMANCE TARGETS

Category 1 - N_2O Emissions Estimation:

Key Output[1]	Total N_2O emissions per season[2] (in g CO_2e/acre)
System-Level Uncertainty[3]	Root Mean Square Error (RMSE) < 200 g N_2O/acre (= ~60 kg CO_2/acre)
Spatial Resolution	≤1 acre
Scale	≥80 acres
Failure Rate	<10% down time during the critical season
Critical Season	Soil thaw through 1 month after the final nitrogen application (exact timing will vary)
System Operation Cost	<$50 /acre/year at commercial scale – for full system deployment and usage, including installation, calibration, and hardware lifetime

[1] For conversion from N_2O to CO_2, see Environmental Protection Agency, Understanding Global Warming Potentials at https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

[2]Here, season is defined as the period beginning at soil thaw and ending at harvest, with the most critical period for N_2O emissions beginning at soil thaw and lasting through the month after the last application of nitrogen.
[3]Uncertainty to include uncertainty of collected data (e.g. sensor, imagery, sampling, and any downtime in operation over the course of a season), compounded by any modeling included as part of the system-level (i.e. >80 acre) N_2O emissions quantification. Uncertainty will be determined through technology testing, funded by ARPA-E and conducted at the ground truth field sites funded by ARPA-E under Phase 1 of the SMARTFARM portfolio (see DE-FOA-0001953: Solicitation on Topics Informing New Program Areas, Topic H: Establishing validation sites for field-level emissions quantification of agricultural bioenergy feedstock production).

Category 2 - Soil Carbon Estimation:

Key Output	MT C/acre
Uncertainty[1]	RMSE < 30 kg C per acre (= ~100 kg CO_2e/acre)[2]
Measurement Depth	≥60 cm
Scale	≥80 acres
System Accessibility[3]	>9 months
System Operation Cost	<$10 /acre/year at commercial scale

[1]Uncertainty to include uncertainty of collected data (e.g. sensor, imagery, sampling, and any downtime in operation over the course of a season), compounded by any modeling included as part of the system-level (i.e. >80 acre) soil carbon quantification. Uncertainty will be determined through technology testing, funded by ARPA-E and conducted at the ground truth field sites funded by ARPA-E under Phase 1 of the SMARTFARM portfolio (see DE-FOA-0001953: Solicitation on Topics Informing New Program Areas, Topic H: Establishing validation sites for field-level emissions quantification of agricultural bioenergy feedstock production).
[2]See EPA Greenhouse Gases Equivalencies Calculator - Calculations and References
[3]System must be able to access fields for soil measurement at any point within at least 9 months of the year – i.e. capable of overcoming most weather conditions, does not disrupt typical field operations

General Requirements for All Field-Deployed Hardware (e.g. sensors, robots, drones):

Environmental Tolerance	-10 to 110 F, 50 mph wind, dust and rain, 0 to 100% Relative Humidity

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $20 million available for new awards, to be shared between FOAs DE-FOA-0002250 and DE-FOA-0002251, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 6-12 awards under FOAs DE-FOA-0002250 and DE-FOA-0002251. 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 36 months. ARPA-E expects the start date for funding agreements to be November 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. 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. All awarded projects requiring proof-of-concept R&D should expect a rigorous go/no-go milestone early in the project.

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

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[42]

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.

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[41] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[42] 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[43] 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.

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

III. Eligibility Information

A. Eligible Applicants

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

1. Individuals

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[44] as the lead for a Project Team,[45] 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,[46] and nonprofits[47] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

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

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

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

3. Foreign Entities

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

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

[45] 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.

[46] The term "Institutions of Higher Education" or "educational institution" is defined in Section IX.

[47] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

Foreign entities must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed or to be formed) under the laws of a State or territory of the United States to receive funding. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate. All work under the ARPA-E award must be performed in the United States. The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/. 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[48]

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

[48] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.

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[49] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[50]

2. INCREASED COST SHARE REQUIREMENT

Large businesses[51] 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 (hereinafter the "Cost Share Grace Period").[52] 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

[49] 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.
[50] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988(c).
[51] The term "For-Profit Organizations (Other than Small Businesses)" or "large business" is defined in Section IX.
[52] The term "small business" is defined in Section IX.

share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.

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

4. Legal Responsibility

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

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

5. Cost Share Allocation

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

6. Cost Share Types and Allowability

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

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

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

- Revenues or royalties from the prospective operation of an activity beyond the period of performance;
- Proceeds from the prospective sale of an asset of an activity;
- 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[53] to meet their cost share obligations under Cooperative Agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under "other transaction" agreements.

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

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

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

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

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

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

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

- Submissions that do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. Submissions Specifically not of Interest

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

- Strategies aimed at nitrogen use efficiency or other management tactics to reduce rather than quantify emissions;
- Systems that solely combine commercially available sensor systems / instrumentation
- Submissions for component solutions (e.g. sensors, models) that cannot produce the desired output on their own, and do not integrate into a larger system solution

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 7 pages in length (inclusive of the Operational Plan and System Cost Section, which is not to exceed two pages) 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

- Clearly identify the problem to be solved with the proposed technology concept. In this case, the problem to be solved relates to the cost, deployment and scalability challenges described in sections I.C.1.1, I.C.1.2, I.C.1.3, D, and E of the FOA.
- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.
- Explain the concept's potential to be disruptive compared to existing or emerging technologies.
- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the Technical Performance Targets in Section I.E of the FOA for the appropriate Technology Category in Section I.D of the FOA.

c. Operational Plan and System Cost

In no more than 2 pages (1 for written portion, 1 for figures) summarize the anticipated business model, including:

- How the system would be deployed and operated. For in-field devices, how deployment, operation and maintenance of field-deployed hardware will not interfere with production operations.
- How the design would accommodate deployment/operation with, at most, minor training,
- How much the system is expected to cost at commercial scale on a $/acre/year basis, broken down by hardware & software components, deployment/labor assumptions, and O&M costs.

d. RISK MATRIX

Identify elements of the solution with the highest anticipated cost and/or uncertainty risks, and the experimental work proposed to reduce those risks.

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

e. PROPOSED WORK

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

f. TEAM ORGANIZATION AND CAPABILITIES

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

- Identify (if applicable) previous collaborative efforts among team members relevant to the proposed effort.

D. Content and Form of Full Applications

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2020]

E. Content and Form of Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 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 APRIL 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.E of the FOA for the appropriate technology Category 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 APRIL 2020]

3. Criteria for Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 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 APRIL 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 APRIL 2020]

B. Administrative and National Policy Requirements

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2020]

C. Reporting

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 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.

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

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

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

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

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

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

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

PI: Principal Investigator.

Project Team: A Project Team consists of the Prime Recipient, Subrecipients, and others performing 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.

Small Business: Small businesses are domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards).

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

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

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

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

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