

**FINANCIAL ASSISTANCE  
FUNDING OPPORTUNITY ANNOUNCEMENT**



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

***REDUCING EMISSIONS USING METHANOTROPHIC ORGANISMS  
FOR TRANSPORTATION ENERGY  
(REMOTE)***

Announcement Type: ~~Modification No. 01~~ **Modification No. 02**  
Funding Opportunity No. DE-FOA-0000881  
CFDA Number 81.135

<b>FOA Issue Date:</b>	March 15, 2013
<b>First Deadline for Questions to <a href="mailto:ARPA-E-CO@hq.doe.gov">ARPA-E-CO@hq.doe.gov</a>:</b>	5 PM ET, April 15, 2013
<b>Submission Deadline for Concept Papers:</b>	5 PM ET, April 22, 2013
<b>Second Deadline for Questions to <a href="mailto:ARPA-E-CO@hq.doe.gov">ARPA-E-CO@hq.doe.gov</a>:</b>	<del>TBD</del> 5 PM ET, July 1, 2013
<b>Submission Deadline for Full Applications:</b>	<del>TBD</del> 5 PM ET, July 8, 2013
<b>Submission Deadline for Replies to Reviewer Comments:</b>	<del>TBD</del> 5 PM ET, August 9, 2013
<b>Expected Date for Selection Notifications:</b>	<del>TBD</del> 5 PM ET, August 2013
<b>Total Amount to Be Awarded</b>	Approximately <del>\$20</del> \$30 million, subject to the availability of appropriated funds.
<b>Anticipated Awards</b>	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.
- ARPA-E will not review or consider noncompliant or nonresponsive applications. For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 and III.C.2 of the FOA.

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

## MODIFICATIONS

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

Mod. No.	Date	Description of Modifications
01	03/26/13	<ul style="list-style-type: none"> <li>Extended first deadline for questions until 5 pm ET April 15, 2013.</li> <li>Extended the submission for Concept Paper submission until 5 pm ET April 22, 2013.</li> <li>Clarified methodology for energy efficiency and carbon yield calculations, Section I.F. Calculation 2.</li> </ul>
02	05/21/13	<ul style="list-style-type: none"> <li>Inserted certain deadlines, including the deadlines for the submission of Full Applications and Replies to Reviewer Comments. See Cover Page and Required Documents Checklist.</li> <li>Inserted language to Section E. Technical Performance Targets, Metric Description Primary Technical Targets 3.1 requiring submission of the REMOTE Calculator Tool to address primary technical target 3.1, Overall Process CapEx.</li> <li>Inserted anticipated dates for selection announcement and award of funding agreements. See Cover Page and Section V.C of the FOA.</li> <li>Revised the following sections of the FOA to provide guidance on required application forms and the content and form of Full Applications and Replies to Reviewer Comments: Required Documents Checklist and Sections IV.D, IV.E, IV.G of the FOA. Applicants are required to use the following templates provided on ARPA-E eXCHANGE (<a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a>) to complete certain parts of their Full Applications: Template Technical Volume of the Full Application, Technical Milestones and Deliverables - Examples and Instructions, Template Summary Slide, Template Summary for Public Release, Template REMOTE Calculator Tool (Required for Category 3 Full Applications) and Template Reply to Reviewer Comments.</li> <li>Inserted criteria that ARPA-E will use to evaluate Full Applications. See Section V.A.2 of the FOA.</li> <li>Inserted criteria that ARPA-E will use to evaluate Replies to Reviewer Comments in Section V.A.3 of the FOA.</li> <li>Inserted program Policy Factors. See Section V.B.1 of the FOA.</li> <li>Inserted Full Application Notification language. See Section VI.A.3 of the FOA.</li> <li>Inserted Administrative and National Policy Requirements. See Section VI.B of the FOA.</li> <li>Inserted Reporting requirements. See Section VI.C of the FOA.</li> <li>Clarified that ARPA-E awards may not be transferred, assigned, or assumed without the prior written consent of a Contracting Officer. See Section VIII.B of the FOA.</li> <li>Clarified that if entities elect to retain title to subject inventions, they must file a patent application in a timely fashion. See Section VIII.F of the FOA.</li> <li>Clarified the conditions under which the U.S. Government may exercise its March-in Rights. See section VIII.G.2 of the FOA.</li> <li>Inserted information concerning annual compliance audits for for-profit Entities. See Section VIII.J of the FOA.</li> <li>Updated total amount to be awarded to \$30 million. See Cover Page and Section II.A.</li> </ul>

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

		<ul style="list-style-type: none"> <li>Updated Application and Submission Information Section to include guidance on REMOTE Calculator Tool for ALL Category 3 Full Applications. See section IV.D.9 of the FOA</li> </ul>
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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.

<b><u>SUBMISSION</u></b>	<b><u>COMPONENTS</u></b>	<b><u>OPTIONAL/ MANDATORY</u></b>	<b><u>FOA SECTION</u></b>	<b><u>DEADLINE</u></b>
Concept Paper	<ul style="list-style-type: none"> <li>Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must include the following: <ul style="list-style-type: none"> <li>Technology Description (2 pages max.)</li> <li>Addendum (2 pages max.)</li> </ul> </li> </ul>	Mandatory	IV.C	5 PM ET, April 22, 2013
Full Application	<p><del>[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]</del></p> <ul style="list-style-type: none"> <li>Each Applicant must submit a Technical Volume in Adobe PDF format by the stated deadline. Applicants must use the Technical Volume template available on ARPA-E eXCHANGE (<a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a>). The Technical Volume must include the following: <ul style="list-style-type: none"> <li>Technical Approach (1 page max.)</li> <li>R&amp;D Tasks (1 page max.)</li> <li>R&amp;D Strategy (20 pages max.)</li> <li>Technology-to-Market Strategy (2 pages max.)</li> <li>Budget Summary (2 pages max.)</li> <li>Qualifications, Experience, and Capabilities (3 pages max. for each Personal Qualifications Summary)</li> <li>Participating Organizations (1 page max.)</li> <li>Prior Collaboration (1 page max.)</li> <li>Management Plan (1 page max.)</li> <li>Multi-Investigator Projects (2 pages max.)</li> <li>Intellectual Property Strategy (no page limit)</li> </ul> </li> <li>The Technical Volume must be accompanied by: <ul style="list-style-type: none"> <li>SF-424 (no page limit, Adobe PDF format);</li> <li>Budget Justification Workbook/SF424A (no page limit, Microsoft Excel format)</li> <li>Technical Milestones and Deliverables (10 pages max.) – Applicants must refer to the Technical Milestones and Deliverables – Instructions and Examples document available on ARPA-E eXCHANGE (<a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a>)</li> <li>Summary for Public Release (1 page max., Adobe PDF format);</li> <li>Summary Slide (1 page limit, Microsoft PowerPoint format) – Applicants must use the Summary Slide template available on ARPA-E eXCHANGE</li> </ul> </li> </ul>	Mandatory	IV.D	5 PM ET, July 8, 2013

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

	<p>(<a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a>);</p> <ul style="list-style-type: none"><li>○ Completed and signed Business Assurances Form (no page limit, Adobe PDF format); and</li><li>○ Completed and signed Other Sources of Funding Disclosure form (no page limit, Adobe PDF format).</li></ul>			
Reply to Reviewer Comments	<p><del>[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]</del></p> <ul style="list-style-type: none"><li>• Each Applicant may submit a Reply to Reviewer Comments in Adobe PDF format. This submission is optional. Applicants must use the Reply to Reviewer Comments template available on ARPA-E eXCHANGE (<a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a>). The Reply may include:<ul style="list-style-type: none"><li>○ Up to 2 pages of text; and</li><li>○ Up to 1 page of images.</li></ul></li></ul>	Optional	IV.E	TBD 5 PM ET, August 9, 2013



## **I. FUNDING OPPORTUNITY DESCRIPTION**

### **A. AGENCY OVERVIEW**

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy, 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 support the creation of transformational energy technologies and systems through funding and managing Research and Development (R&D) efforts. Originally chartered in 2007, the Agency was first funded through the American Recovery and Reinvestment Act of 2009. Since that time, the Agency has funded about 285 projects totaling approximately \$770 million across the entire technology landscape.<sup>1</sup>

The mission of ARPA-E is to identify and fund research to translate science into breakthrough energy technologies that are too risky for the private sector and that, if successfully developed, will create the foundation for entirely new industries. Successful projects will address at least one of ARPA-E's two Mission Areas:

1. Enhance the economic and energy security of the United States through the development of energy technologies that result in:
  - a. reductions of imports of energy from foreign sources;
  - b. reductions of energy-related emissions, including greenhouse gases; and
  - c. improvement in the energy efficiency of all economic sectors; and
2. Ensure that the United States maintains a technological lead in developing and deploying advanced energy technologies.

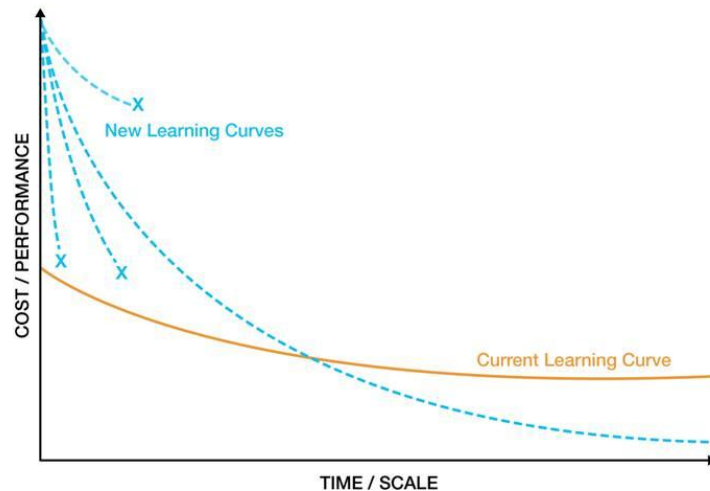
**ARPA-E funds applied research and development.** ARPA-E exists to fund applied research and development, defined by the Office of Management and Budget as a “study (designed) to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met” and as the “systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.” ARPA-E funds technology-focused applied research to create real-world solutions to important problems in energy creation, distribution and use and, as such, will not support basic research, defined as a “systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications towards processes or products in mind.” While it is anticipated that in some instances some minor aspects of fundamental science will be clarified or uncovered during the conduct of the supported applied research, the major portion of activities supported by ARPA-E are directed towards applied research and development of new technologies.

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<sup>1</sup> Information on ARPA-E's projects is available at <http://arpa-e.energy.gov/?q=projects>.

While all technology-focused applied research will be considered, two instances are especially fruitful for the creation of transformational technologies:

- the first establishment of a technology upon recently elucidated scientific principles; and
- the synthesis of scientific principles drawn from disparate fields that do not typically intersect.



**Figure 1:** Description of transformational and disruptive technologies in terms of cost, performance, and scale. ARPA-E supports research that establishes new learning curves. A transformational technology becomes disruptive after passing the tipping point.

**ARPA-E exists to support transformational, rather than incremental research.** Technologies exist on learning curves (Figure 1). Following the creation of a technology, refinements to that technology and economies of scale that accrue as manufacturing and widespread distribution develop drive technology down that learning curve until an equilibrium price is found. While this incremental improvement of technology is important to the ultimate success of a technology in the marketplace, ARPA-E exists to fund transformational research – i.e., research that creates fundamentally new learning curves rather than moving existing technologies down their learning curves.

**ARPA-E funded technology has 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. Energy technologies typically become disruptive at maturity rather than close to inception and the maturation of nascent technologies often require significant incremental development to **drives drive** the technology down its natural learning curve to its ultimate equilibrium (see Figure 1 above). Such

development might include modification of the technology itself, the means to produce and distribute that technology, or both. Thus, while early incarnations of the automobile were transformational in the sense that they created a fundamentally new learning curve for transportation, they were not disruptive, because of the unreliability and high cost of early automobiles. Continuous, incremental refinement of the technology ultimately led to the Ford Model T: as the first affordable, reliable, mass-produced vehicle, the Model T had a disruptive effect on the transportation market.

ARPA-E will not support technology development for extended periods of time; rather, ARPA-E supports the initial creation of technology. Following initial testing of the first prototype of a device, a system, or a process, other Federal agencies and the private sector will support the incremental development necessary to bring the technology to market.

While ARPA-E does not require technologies to be disruptive at the conclusion of ARPA-E funding, ARPA-E will not support technologies that cannot be disruptive even if successful. Examples of such technologies are approaches that require elements with insufficient abundances of materials to be deployed at scale, or technologies that could not scale to levels required to be impactful because of, for example, physical limits to productivity.

***ARPA-E will not support basic research aimed at discovery and fundamental knowledge generation, nor will it undertake large-scale demonstration projects of existing technologies.***

ARPA-E is not a substitute for existing R&D organizations within the Department of Energy, but rather complements existing organizations by supporting R&D objectives that are transformational and translational. Applicants interested in receiving basic research financial assistance should work with the Department of Energy's Office of Science (<http://science.energy.gov/>). Similarly, projects focused on the improvement of existing technology platforms may be appropriate for support by the applied programs – for example, 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://nuclear.energy.gov/>), and the Office of Electricity Delivery and Energy Reliability (<http://energy.gov/oe/office-electricity-delivery-and-energy-reliability>).

## **B. PROGRAM OVERVIEW**

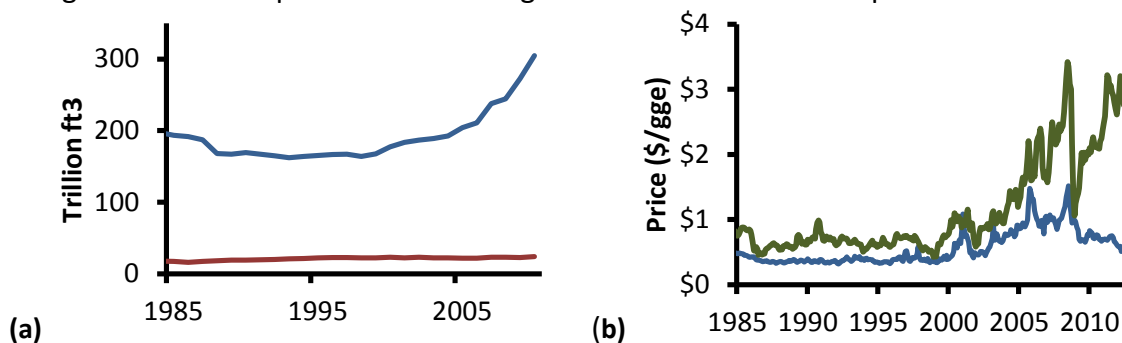
This program seeks to fund the development of bioconversion technologies that transform our ability to convert methane into liquid fuels. Of interest are biological routes to improve the rates and energy efficiencies of methane activation and subsequent fuel synthesis, as well as approaches to engineer high-productivity methane conversion processes. Within this program, three technical categories are considered: (1) high-efficiency biological methane activation, (2) high-efficiency biological synthesis of liquid fuels, and (3) process intensification approaches for biological methane conversion. The potential impacts of this FOA includes increasing the economic and energy security of the nation through production of low-cost, liquid transportation fuels with lower emissions than petroleum-based fuels.

### ***Benefits of Natural Gas to Liquids for Transportation Fuels***

The benefits of converting natural gas to liquid fuels for use in transportation have long been recognized. First, the existing transportation infrastructure is based on liquids, and such fuels can be conveniently “dropped in” without substantial changes in vehicles. Second, liquid fuels from methane have lower emissions than petroleum-based fuels. Liquid fuel produced from methane decreases emissions by up to 50%, compared to unconventional petroleum,<sup>2</sup> and decreases particulate matter by up to 40%, compared to combustion of conventional diesel.<sup>3</sup> Further, methane is responsible for 10% of the nation’s greenhouse gas emissions (on a CO<sub>2</sub> equivalent basis), in part because it’s global-warming potential is twenty times greater than that of CO<sub>2</sub> over a 100-year period.<sup>4</sup> Technologies capable of capture and conversion of methane will help mitigate the global-warming potential of these emissions.

Horizontal drilling technology, in tandem with hydraulic fracturing, has led to significant increases in proven U.S. natural gas reserves (Figure 2a). Recent gas resource estimates by the U.S. Geological Survey and the U.S. Energy Information Agency assert that the U.S. has 2,000 trillion ft<sup>3</sup> of technically recoverable natural gas.<sup>5,6</sup> On an energy basis, this amount of natural gas could fully satisfy the nation’s demand for transportation energy, without compromising its use in all other sectors, for approximately 50 years, based on current rates of consumption.<sup>2</sup>

In addition to the long-term projected supply of natural gas, the historical and recently increasing price spread between natural gas and wholesale gasoline (Figure 2b) encourages natural gas use for transportation. This is significant because the transportation sector is the



<sup>2</sup> “America’s Energy Future: Technology and Transformation” (National Academy of Sciences, 2009).

<sup>3</sup> U.S. Department of Transportation. OK-26-7015-00. Evaluation of Ultra-Clean Fischer-Tropsch Diesel Fuel in Transit Bus Applications, 2010.

<sup>4</sup> U.S. Environmental Protection Agency, *DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2011*. Feb 2013.

<sup>5</sup> “National Oil and Gas Assessment.” Energy Resources Program. February 28, 2013. U.S. Geological Survey. March 2013. <<http://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment.aspx>>.

<sup>6</sup> U.S. Energy Information Administration, *Annual Energy Outlook 2012* (EIA Publication, DOE/EIA-0383, 2012; <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>).

**Figure 2. (a)** Estimated U.S. annual natural gas consumption (red) and proven U.S. natural gas reserves (blue). **(b)** U.S. natural gas citygate (blue) and gasoline wholesale prices (green) on an equivalent energy basis.<sup>7</sup> GGE is defined as gallons of gasoline equivalent on an energy basis.

single greatest component of U.S. dependence on imported oil. In 2010, 94% of U.S. transportation energy came from petroleum, nearly half of which came from foreign sources.<sup>7</sup> Petroleum represented nearly 40% of the \$735 billion U.S. trade deficit of goods in 2012. By expanding the use of domestic natural gas for transportation, the U.S. could completely eliminate the need for imported petroleum and significantly reduce the national trade deficit.<sup>8</sup>

Switching to alternative sources of energy for transportation is not straightforward. While it is conceivable to use natural gas directly for ground transportation either as compressed natural gas (CNG) or as liquefied natural gas (LNG), both the nation's distribution infrastructure and its current transportation fleet demand fuels that combine high energy density with broad compatibility across all modes of transportation (Table 1). The efficient, cost-effective conversion of methane to a liquid fuel at any scale of production would be transformative in enabling natural gas as a transportation fuel.

### ***Barriers of Natural Gas to Liquids for Transportation Fuels***

The direct use of natural gas in transportation is limited due to the inherent low energy density of natural gas and infrastructure changes that are required, which leads to reduced vehicle range and high storage cost (Table 1).<sup>9</sup> Critical challenges associated with the lack of refueling infrastructure for CNG, and the high cost of compression and storage are being addressed by ARPA-E's MOVE program.<sup>10</sup> A complementary approach, chemically converting natural gas to

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<sup>7</sup> U.S. Energy Information Administration, *Annual Energy Outlook 2012* (EIA Publication, DOE/EIA-0383, 2012; <http://www.eia.gov/forecasts/archive/aeo12/index.cfm>).

<sup>8</sup> "Foreign Trade." March 14, 2013. United States Census Bureau. March 2013. <<http://www.census.gov/foreign-trade/index.html>>.

<sup>9</sup> National Petroleum Council, *Draft. Future Transportation Fuels Study* (NPC Publication, 2012; [http://www.npc.org/FTF-report-080112/Natural\\_Gas\\_Analysis-080112.pdf](http://www.npc.org/FTF-report-080112/Natural_Gas_Analysis-080112.pdf)).

<sup>10</sup> "Methane Opportunities for Vehicular Energy." 2013. ARPA-E. March 2013. <<http://arpa-e.energy.gov/?q=arpa-e-programs/move>>.

**Table 1.** Comparison of the properties of natural gas as a transportation fuel in light duty vehicles.

Fuel	Energy Density (MJ/L)	Storage Conditions	Energy Efficiency, <sup>11,12,13,14,15</sup>	Conversion Cost (\$/gge) <sup>11</sup>	Cost of Storage Tank, (\$/gge) <sup>11</sup>
Natural Gas	0.036	STP	Not applicable	Not applicable	Not applicable
CNG	9.2	3600 psi, ambient	>94%	\$0.71-0.79	\$300-450
LNG	22.2	-162°C, low pressure	70-90%	\$0.99-1.08	\$200-500
FT Diesel	34.5	STP	≤60%	\$1.50	\$10

liquid fuels (GTL), is a proven technology that increases volumetric energy density, and avoids the added costs of gas storage and distribution. However, the current conversion approach through Fischer-Tropsch (FT-GTL) is challenged by both high capital costs and low conversion efficiencies (Table 1; Figure 3).

The high capital costs of FT-GTL result from its technologically complex, multi-step process, which includes: (1) converting methane to synthesis gas (syngas, a mixture of predominantly CO and H<sub>2</sub>), (2) catalyzing hydrocarbon formation from syngas, and (3) separating a broad distribution of products and upgrading them, which all require numerous temperature and pressure changes. Syngas production is the single largest contributor to capital cost (Figure 3a). Only large facilities are able to drive down capital costs per unit, manage heat efficiently, and cost effectively separate multiple products that are all required for the profitability of the FT-GTL approach. The overall result is that large facilities have not been scaled down efficiently, and therefore must be built near large gas fields with multi-billion dollar capital investments (Figure 3b). Logically, this has spurred development of small-scale GTL technologies that seek new ways to scale down and intensify both syngas generation and FT processes.<sup>16,17</sup>

### **Biological Approach for Natural Gas to Liquids**

In principle, bioconversion of methane, the main component of natural gas, to fuels with high specificity and high process energy efficiency can be achieved under a single set of mild

<sup>11</sup> National Petroleum Council, *Draft. Future Transportation Fuels Study* (NPC Publication, 2012; [http://www.npc.org/FTF-report-080112/Natural\\_Gas\\_Analysis-080112.pdf](http://www.npc.org/FTF-report-080112/Natural_Gas_Analysis-080112.pdf)).

<sup>12</sup> ARPA-E, *Methane Opportunities for Vehicular Energy (MOVE)* (ARPA-E Publication, DE-FOA-0000672, 2012; <https://arpa-e-foa.energy.gov/Default.aspx?Archive=1#Foalddc1d731e-f2cf-4be9-b6ac-ab315582d000>).

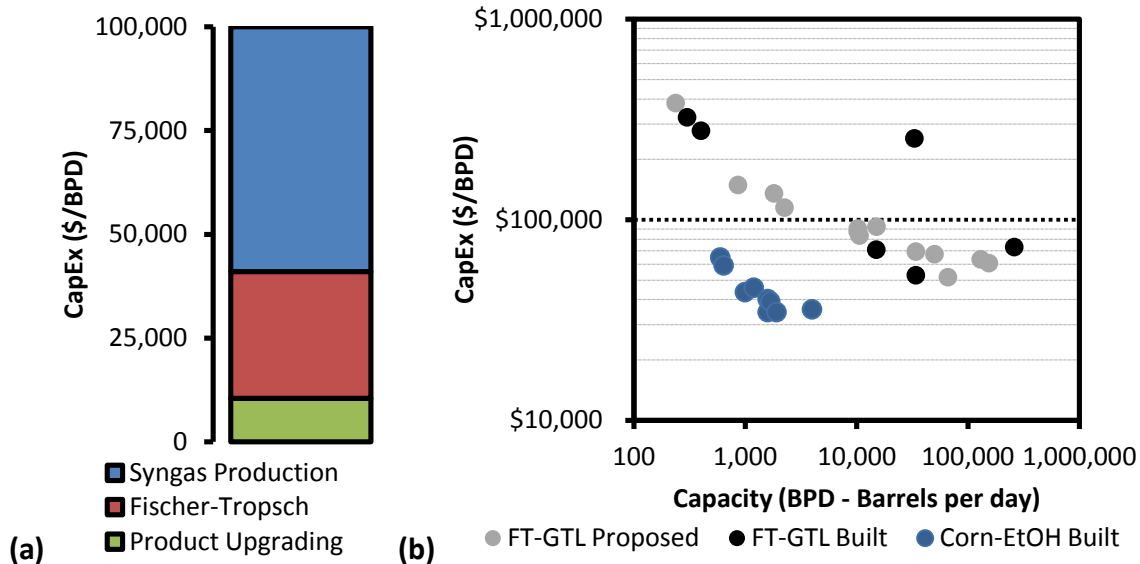
<sup>13</sup> National Renewable Energy Laboratory, *Comparison of CNG and LNG Technologies for Transportation Applications* (NREL Publication, NREL/TP-230-4638, 1992; <http://www.afdc.energy.gov/pdfs/2451.pdf>).

<sup>14</sup> "Gas-to-Liquids." Energy Sources. April 2012. Chevron. March 2013. <http://www.chevron.com/deliveringenergy/gastoliquids/>.

<sup>15</sup> "Pearl GTL - an overview." Pearl GTL. Shell Global. March 2013. <http://www.shell.com/global/aboutshell/our-strategy/major-projects-2/pearl/overview.html>.

<sup>16</sup> "Developing marginal oil and gas fields." Our products. 2013. CompactGTL. March 2013. <http://compactgtl.com/our-products/>.

<sup>17</sup> "Overview." Technology. Velocys. March 2013. <http://velocys.com/ocge01.php>.



**Figure 3. (a)** Relative capital expense (CapEx) contributions for a representative Fischer-Tropsch facility. **(b)** Comparison of CapEx vs. Capacity for Fischer-Tropsch and corn-ethanol facilities on an equivalent energy basis. FT data is combination of engineering studies as well as built facilities, which includes commercial and demonstration units,<sup>18</sup> whereas corn-ethanol data is entirely from built commercial facilities.<sup>19</sup> BPD is defined as barrel of oil equivalent per day. FT-GTL is defined as gas-to-liquids approaches that use Fischer-Tropsch technology.

conditions. Moreover, this direct route to conversion, without relying on upstream unit operations for syngas production, has the potential to reduce capital expenses (CapEx) by more than 50% (Figure 3a). In combination, these factors might lead to a significantly smaller capital investment for bioconversion than for current commercial GTL processes. Ethanol fermentation is an excellent example of how bioconversion technologies can be deployed at commercial scale. In this process, yeast convert sugars from corn or sugarcane to ethanol at a high metabolic and process energy efficiency (97%, 81%,<sup>20</sup> Sec. I.F, Table 2, Reaction 1) and with an ethanol product specificity greater than 90%. This in turn leads to a process that is less technologically complex than a FT process and therefore supports deployment at smaller scales and with significantly lower CapEx per BPD (defined as barrel of oil equivalent per day) than FT plants (Figure 3b). As a consequence, the overall capital investment on corn-ethanol facilities ranges from \$50-\$150 million, enabling easier financing and more widespread deployment than for commercial FT facilities.

Despite advantages outlined above, the microbial synthesis of fuels or fuel precursors from methane using aerobic methanotrophs that activate methane with methane monooxygenase (MMO) leads to an energy efficiency less than 51%. As illustrated in Figure 4a, a hypothetical

<sup>18</sup> P. J. A. Tijm, *Gas to liquids, Fischer-Tropsch, Advanced Energy technology, Future's Pathway* (Peter Tijm, 2010).

<sup>19</sup> T. M. Schmit et al, *Biomass Bioenergy* **33**, 1442-1451 (2009).

<sup>20</sup> U.S. Department of Agriculture, *2008 Energy Balance for the Corn Ethanol Industry* (USDA Publication, Agricultural Economic Report Number 846, 2010; [http://www.usda.gov/oce/reports/energy/2008Ethanol\\_June\\_final.pdf](http://www.usda.gov/oce/reports/energy/2008Ethanol_June_final.pdf)).



methanotrophic bacterium that synthesizes *n*-butanol from methane in a bioconversion pathway has two problems: methane is activated inefficiently ( $E_{\text{eff}} = 66\%$ ) and then formaldehyde is converted into fuel inefficiently ( $E_{\text{eff}} = 78\%$ ). Thus, even if an organism fully leveraged the most recent developments in synthetic biology and industrial biotechnology, bioconversion through MMO will have difficulty being cost effective or disruptive to the fuel market.<sup>21</sup>

### **Program Challenges**

This program envisions the development of transformative bioconversion technologies that are capable of producing liquid fuels economically from natural gas at less than \$2 per gallon of gasoline equivalent and at levels sufficient to meet U.S. demand for transportation fuels. These technologies can support natural gas bioconversion facilities with a lower capital cost and at smaller scales than current GTL facilities. Such small-scale deployments will enable the use of natural gas resources that are currently flared, vented, or emitted, not only recovering wasted resources but also significantly mitigating greenhouse gas emissions. Technologies that support this vision will activate methane efficiently, synthesize liquid fuels at high carbon yield and energy efficiency, and utilize engineering processes that have high volumetric rates of both methane utilization and product synthesis.

Major advances and federal initiatives in synthetic biology and metabolic engineering have accelerated the underlying science toward practical applications.<sup>22,23</sup> The discovery of alternative biochemical routes to either aerobic or anaerobic activation of methane have inspired new approaches to metabolic pathway engineering.<sup>24,25</sup> Advances in gas-intensive fermentations have been made by both private and Federal investment (e.g. ARPA-E's Electrofuels program and the Department of Energy's Bioenergy Technology Office).<sup>26,27</sup> Together, such developments encourage us to address anew such long-standing challenges as: (1) the efficient activation of methane, (2) the conversion of molecules derived from methane activation into useful fuels without the waste of energy and the release of CO<sub>2</sub>, and (3) the development of innovative bioprocesses to achieve high rates of gas transfer and product synthesis using engineered biocatalysts.

The three primary challenges addressed by this program are the low carbon yield, low energy efficiency and slow kinetics in the process of bioconversion of methane to liquid fuels. These

<sup>21</sup> ARPA-E internal analysis, highlighted in Figure 5.

<sup>22</sup> "Research." Joint Bioenergy Institute. March 2013. <<http://jbei.org/>>.

<sup>23</sup> Y. H. Wang et al, *Annu Rev Chem Biomol Eng*, 13 Feb 2013 (10.1146/annurev-chembioeng-061312-103351)

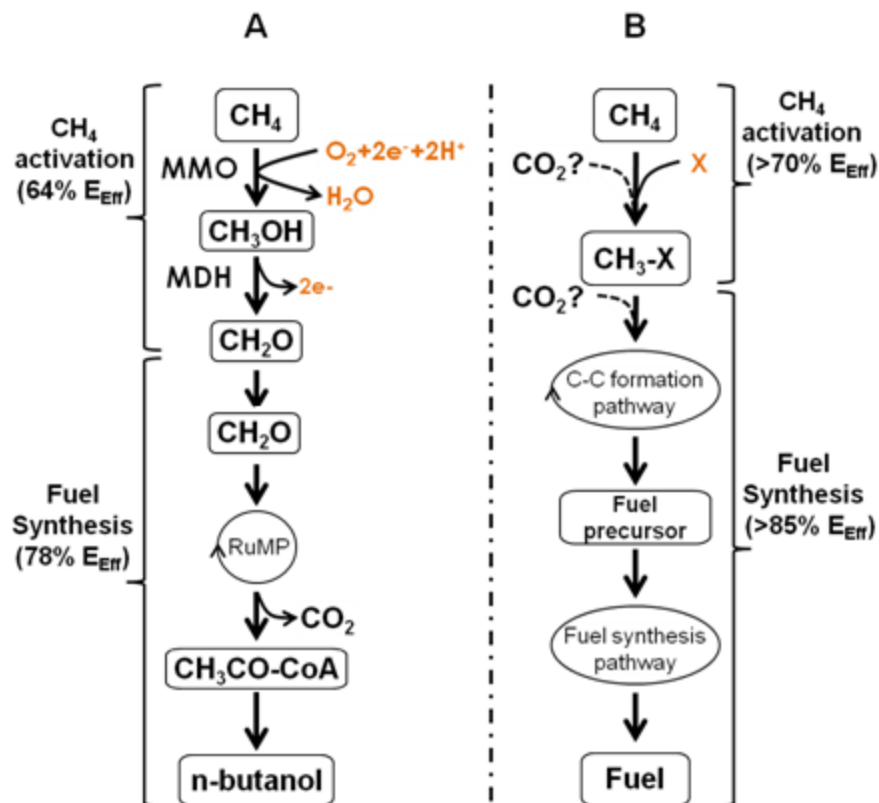
<sup>24</sup> S Shima et al, *Nature*, **481**, 98-101 (2011).

<sup>25</sup> L Chistoserdova et al, *Genome Biol*, **6**,208 (2005), doi:10.1186/gb-2005-6-2-208.

<sup>26</sup> "Electrofuels." 2013. ARPA-E. March 2013. <<http://arpa-e.energy.gov/?q=arpa-e-programs/electrofuels>>.

<sup>27</sup> "Bioenergy Technologies Office." Energy Efficiency and Renewable Energy. Feb 2, 2013. U.S. Department of Energy. March 2013. <<http://www1.eere.energy.gov/biomass/>>.





**Figure 4.** Schematic of the pathways involved in the conversion of methane to **(a)** n-butanol in an engineered aerobic methanotrophic bacterium or **(b)** another fuel molecule through efficient metabolic pathways for methane conversion to fuel. The reaction network is divided into two metabolic blocks: i) activation of methane to the metabolic intermediate formaldehyde (CH<sub>2</sub>O); and ii) conversion of formaldehyde to n-butanol. Stoichiometry, energy efficiency and  $\Delta G^\circ$  are calculated for the reactions pathways (a) and (b) in Sec. I.F, Table 2, Reactions 2 and 3 respectively. Abbreviations: MDH, methanol dehydrogenase; MMO, methane monooxygenase; RuMP, ribulose monophosphate pathway; X, methane-activating species.

challenges are discussed below in the context of the two key components of the program, biocatalyst engineering and bioprocess intensification.

**Biocatalyst Engineering.** As noted previously, the energy efficiency for the bioconversion of methane to liquid fuels by engineered aerobic methanotrophs is low. This low efficiency provides a significant opportunity for improvement, both in activation and in fuel synthesis. For example, the standard Gibbs free energy,  $\Delta G^\circ$ , of the conversion of methane to *n*-butanol is 10 times larger than the comparable  $\Delta G^\circ$  of conversion of glucose to ethanol during yeast fermentation (Sec. I.F, Table 2, Reaction 2). Most of this energy loss is released in the form of heat ( $\Delta H^\circ = -2669 \text{ kJ/mol}_{n\text{-BuOH}}$ , for the overall pathway shown in Figure 4a), and cannot be recovered in practice.

More efficient metabolic pathways can be envisioned and Figure 4b illustrates this concept, e.g.  $4\text{CH}_{4,(g)} + 2\text{O}_{2,(g)} \rightarrow \text{C}_4\text{H}_{10}\text{O}_{(l)} + 3\text{H}_2\text{O}_{(l)}$ ,  $\Delta G < 0$  (Sec. 1.E, Table 2, Reaction 3). In this example, the activation of methane to a metabolic intermediate like methanol is achieved *without* the consumption of electrons, which provides an efficiency of 80% (Sec. 1.E, Table 2, Reaction 6). Conversion of the activated intermediate (methanol) to the final fuel molecule (*n*-butanol) then proceeds through a pathway that retains all of the carbon in the final product, giving an energy conversion efficiency of 91% (Sec. 1.E, Table 2, Reaction 7). Overall, the theoretical energy efficiency of this designed pathway is 77% and its theoretical carbon efficiency is 100%.

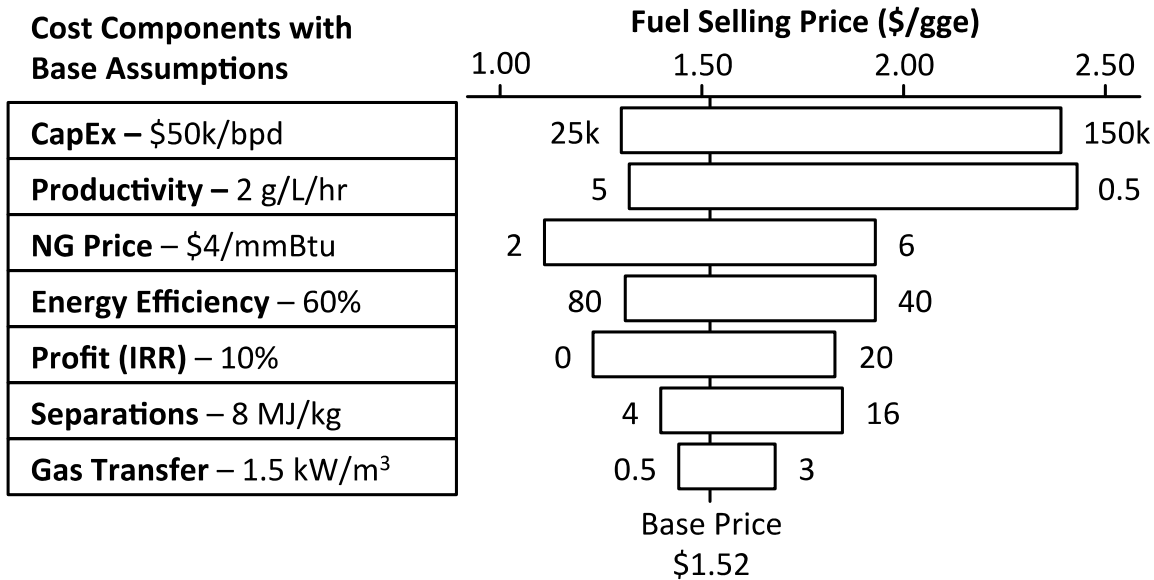
**Bioprocess Intensification.** A practical process for bioconversion of methane to fuels needs to address a kinetic challenge as well. Several limitations are apparent: (1) the rate of mass transfer of methane to the liquid phase due to low gas solubility, (2) the low rate of product synthesis inherent to slow enzyme kinetics from methane activation and fuel synthesis, and (3) the low catalyst loading in traditional bioreactors. In addition, such a process could also run into unreasonable energy requirements for product separation, as determined by the choice of the fuel molecule and method of separation.

The kinetic limitations to gas transfer involve both methane and oxygen (if it is used as an oxidant), and are determined not only by the low solubility of these gases in water, but also by their flammability limits. Additionally, high gas transfer rates can impose a high energetic penalty unless mass transfer coefficients are improved, and contact surface area relative to the reactor volume is increased. Achieving high rates of conversion will also result in high volumetric heat loss, requiring the removal of excess heat from the reactor to maintain high biological activity.

The kinetic challenges of a biological process are compounded by the slow rates of methane activating enzymes and by the large molecular weight of the enzyme complex. To integrate these enzymes in an industrially relevant process, it is necessary to achieve high energy efficiency and catalyst loading, without impairing the catalytic turnover of biological methane activation. This will require new catalysts capable of high enzyme concentrations within the cell, and high cell densities within the reactor.

### **Program Approach**

The program seeks new, transformational technologies for bioconversion of methane to liquid fuels. These technologies will produce fuel more cost competitively, with reduced greenhouse gas emissions compared to petroleum-derived fuels, by addressing key system level metrics. To evaluate the impact of such technologies quantitatively, ARPA-E conducted a preliminary techno-economic analysis that shows key components of a biological process, that converts methane into a liquid fuel, and illustrates the sensitivity of each on the final fuel selling price (Figure 5). This analysis suggests that the fuel selling price is most sensitive to system variables such as CapEx and volumetric productivity, while feedstock natural gas price and the energy efficiency of conversion both play significant roles. These results emphasize the



**Figure 5.** Major cost components of a biological gas-to-liquids process and base values are tabulated to show a sensitivity analysis, left. The Tornado chart illustrates how the variation in a single parameter influences the overall cost under n<sup>th</sup> plant assumptions, right. The values to the left and right of the bar are variations on base parameters and show the fuel selling price when all other base assumptions are held constant. The underlying process model was parameterized and Aspen-based to enable scenario analysis and couples the biological reactions and chemical unit operations.

need to reduce CapEx while improving energy efficiency. These factors are determined by both the efficiency of bioconversion and the productivity of the reactor, and are addressed in this FOA by explicitly considering the tradeoffs between cost and performance. For example, an improvement in energy efficiency not only reduces the cost by lowering the amount of feedstock required but also by reducing cooling loads and equipment sizes. Likewise, an improvement in reactor productivity not only reduces CapEx by reducing reactor volume, but also by reducing the size of other support equipment.

Since the major cost drivers are interlinked, a system demonstrating low CapEx will require high productivity as well as both high metabolic and process efficiency. To achieve this combination, both system level and component level targets in three categories are established in this FOA. Breakthroughs are needed in all three areas, and are synergistic: (1) high-efficiency biological methane activation, (2) high-efficiency biological synthesis of liquid fuel, and (3) process intensification approaches for biological methane conversion. These areas are considered separately below:

*High-efficiency biological activation of methane.* This program seeks more energy efficient biological activation than methane monooxygenase enzymes, without sacrificing kinetics for efficiency. Examples of breakthrough technical approaches include, but are not limited to: more

efficient aerobic activation, anaerobic or other oxygen-independent activation, and *de novo* activation routes to metabolically compatible intermediates (Sec. I.F., Table 2).

*High-efficiency biological synthesis of fuel.* This program also seeks metabolic pathways for fuel synthesis that result in high energy efficiency and carbon yield. Efficient conversion of activated methane molecules into fuel is critical to the success of this program. For example, more efficient routes of methane activation are achieved, pathways that direct all 6 electrons from a methyl intermediate to a final fuel are of interest (e.g. Sec. I.F., Table 2, Reactions 7, 9). In addition, pathways that can realize 100% carbon conversion efficiency, as well as those that can consume both CH<sub>4</sub> and CO<sub>2</sub> are of particular interest.

*Process intensification approaches for biological methane conversion.* This program also seeks bioreactor and process designs that enable the combination of high gas transfer rates and high loading of active biocatalyst in support of high volumetric productivities. Of particular interest are designs that include: increasing heat-transfer, minimizing product inhibition, and reducing complexity and energy penalties.

### **C. PROGRAM OBJECTIVES**

Consistent with ARPA-E's mission, this FOA seeks novel approaches to convert methane into liquid transportation fuels. The broader vision of the program is the development of bioconversion technologies that have reduced emissions and lower cost than FT GTL at all scales. Namely > 60% energy efficiency conversion of methane to a liquid fuel (more energy dense than *n*-butanol,  $\geq 26.8$  MJ/L) in a process that can be deployed across scales (CapEx < \$50,000/BPD). The synergistic impact of these technologies would lead to a cost-effective alternative to FT GTL that can be deployed flexibly to capture remote or flared gas, in addition to pipeline gas.

The first specific objective of this program is to develop new, more efficient, biological routes to activate methane. Enzyme-based technologies capable of activating methane to an intermediate with a feasible pathway to fuel production are of particular interest.

The second specific objective of this program is to engineer metabolic pathways for the conversion of activated methane to a liquid fuel with high energy density. Pathways that use both carbon and energy efficiently without sacrificing pathway kinetics are of special interest.

The third specific objective of this program is to develop process intensification applied to methane bioconversion. Specifically, the process-intensified system should address three aspects, (1) the low solubility of methane in the reaction medium (Sec. I.F, Calc 1), (2) the low synthesis rate of a biological system, and (3) the flammability of methane in air. High system productivities necessary for eventual technology deployment to remote methane sources should be demonstrated.

#### **D. TECHNICAL CATEGORIES OF INTEREST**

This program is focused on supporting biological and system concepts for methane conversion to liquid fuels in one or more of the following categories:

- **CATEGORY 1: High-Efficiency Biological Activation of Methane**
- **CATEGORY 2: High-Efficiency Biological Synthesis of Fuel**
- **CATEGORY 3: Process Intensification Approaches for Biological Methane Conversion**

Applications must have a well-justified and realistic potential to meet or exceed all of the Primary Technical Targets in one or more of the three categories listed above by the end of the project period.

Examples of technical approaches include, but are not limited to:

- 1) Oxygen-dependent routes for biological methane activation that consume fewer than two electrons during activation;
- 2) Oxygen-independent routes for biological methane activation;
- 3) Biological fuel synthesis pathways that can convert all of the input carbon to a liquid within thermodynamic constraints ( $\Delta G < 0$  under process conditions);
- 4) Biological fuel synthesis pathways that consume both  $\text{CH}_4$  and  $\text{CO}_2$ ;
- 5) Fuel molecules that enable separation and intensification processes;
- 6) Reactor systems that integrate biological catalysts and improve one or more of: catalyst loading, rates of gas- and heat-transfer, and product toxicity and inhibition;
- 7) Reactor systems that enable high gas-transfer rates across scales at low cost, with low complexity, and without severe energetic penalty. Such systems may require integration of traditionally distinct unit operations; and,
- 8) Reactor systems and conversion strategies that avoid safety issues with methane flammability by design.<sup>28</sup>

The ideal Project Team will have relevant expertise in multiple areas, including biochemical engineering, chemical engineering, mechanical engineering, biology, and chemistry and will demonstrate a high level of understanding of biological systems, process design and integration. In particular, Projects Teams in Category 3 are expected to have expertise in multiple technical disciplines needed to combine the process with a relevant biological conversion pathway.

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<sup>28</sup> "NFPA 704: Standard system for the identification of the hazards of materials for emergency response" (National Fire Protection Agency Report 704, 2012). Methane is flammable in air within the range of 5-15% v/v.

## E. TECHNICAL PERFORMANCE TARGETS

### 1. CATEGORY 1: High-Efficiency Biological Activation of Methane

The final research objective for Category 1 is a biological system capable of activation of methane at a sustained rate of 1 g<sub>CH<sub>4</sub></sub>/L/hr or greater. Category 1 projects should include an enzyme-based technology capable of activating methane to an intermediate with a feasible pathway to fuel production that is capable of meeting the following primary technical targets:

#### Primary Technical Targets

ID	Parameter	Primary targets
1.1	Energy Efficiency	> 66%
1.2	Turnover Frequency	> 10/s
1.3	Specific Activity	> 5 μmol <sub>CH<sub>4</sub></sub> /g <sub>total cell protein</sub> /s

#### Metric Descriptions – Primary Technical Targets

- 1.1 The energy efficiency of methane activation must be > 66% to meet the overall process energy efficiency goal of > 60%. Applicants should provide a well-justified description and calculations of how they will achieve this metric. Energy efficiency of methane activation should exceed that of the native methane monooxygenase reaction to biologically activate methane with oxygen (Figure 4a; Sec. I.F, Table 2, Reactions 4, 8; Sec. I.F, Calc 2).
- 1.2 The enzyme turnover frequency must reach > 10/s to meet the overall process rate goal of > 2 g<sub>fuel</sub>/L/hr. Applicants should provide a credible path to achieve this metric, where turnover frequency is explicitly defined as the number of catalytic turnovers per catalyst per second at saturation with methane, and should be considered analogous to  $k_{cat}$  (Sec. I.F, Calc 3).
- 1.3 Applicants should provide a well-justified description and calculations of how they will achieve this metric, noting the expected molecular weight and the fraction of the activating protein of the total cell protein.

### 2. CATEGORY 2: High-Efficiency Biological Synthesis of Fuel

The final research objective for Category 2 is a fuel with an energy density  $\geq 26.8$  MJ/L that is produced in a 1 L bioreactor with a titer of 10 g<sub>fuel</sub>/L. The choice of input molecules to the fuel synthesis pathways should be capable of satisfying the Category 1 Technical Targets. Category 2 projects must include a metabolic system that must meet the following primary technical targets:

### **Primary Technical Targets**

<b>ID</b>	<b>Parameter</b>	<b>Primary targets</b>
2.1	Pathway Energy Efficiency	> 64%
2.2	Pathway Carbon Yield	> 67%
2.3	Pathway Kinetics	> 1 g <sub>fuel</sub> /g <sub>CDW</sub> /hr

### **Metric Descriptions – Primary Technical Targets**

- 2.1 “Pathway Energy Efficiency” is based upon comparing the final fuel molecule product and the reactant molecule, derived from methane activation. The energy efficiency for fuel synthesis must be > 64% to meet the overall process energy efficiency objective of > 60%. Therefore applicants that address Category 2 should propose technologies for more efficient fuel synthesis pathways than those described in Figure 4a; Sec. I.F, Table 2, Reaction 5; and Sec. I.F. Calc 2. This should include justification for selecting the reactant molecule and a description of a potential route to produce the starting activated molecule. Applicants should numerically justify how they will achieve this metric.
- 2.2 “Pathway Carbon Yield” is defined as the number of carbon atoms in the fuel product divided by the number of carbon atoms in reactant. Engineering a fuel synthesis pathway with carbon yield > 67% is necessary to achieving a process with a CO<sub>2</sub> footprint similar to or better than gasoline/diesel from conventional oil. Therefore applicants that address Category 2 should propose technologies for routes with a higher carbon yield than those described in Figure 4a; Sec. I.F, Table 2, Reaction 5; and Sec. I.F. Calc 2. Applicants should numerically justify how they will achieve this metric.
- 2.3 “Pathway Kinetics” must be capable of exceeding 1 gram of fuel produced per gram of cell dry weight per hour. If cell dry weight basis is not appropriate, please provide and justify a similar metric for the proposed system. Applicants must numerically justify how they will achieve this metric.

### **3. CATEGORY 3: Process Intensification Approaches for Biological Methane Conversion**

The final research objective for Category 3 is a prototype bioreactor capable of producing 1 liter of fuel per week from methane as a feedstock, producing a fuel with energy density  $\geq 26.8$  MJ/L with an emphasis on compatibility with existing distribution infrastructure. Specifically, the system must demonstrate high reactor and system productivities necessary for eventual technology deployment to remote methane sources and is capable of meeting the following primary technical targets:



### Primary Technical Targets

ID	Parameter	Primary targets
3.1	Overall Process CapEx	< \$100,000/BPD (when calculated for a 500 BPD scale)
3.2	Process Energy Efficiency	> 25% (overall) > 35% (metabolic)
3.3	Process Intensification	> 10 g <sub>fuel</sub> /L <sub>system</sub> /hr > 25 g <sub>fuel</sub> /L <sub>reactor</sub> /hr > 50 g <sub>CH4</sub> /L <sub>reactor</sub> /hr > 400 kW/m <sup>3</sup> heat removal

### Metric Descriptions – Primary Technical Targets

- 3.1 Applicants should numerically justify how this metric can be achieved and should provide results from preliminary techno-economic calculations to address process equipment and balance of plant costs. ~~References for cost estimates of unit operations should be included.~~ To do so, Category 3 Applicants are required to submit a completed REMOTE Calculator Tool template as part of their Full Application. The purpose of the REMOTE Calculator Tool template is to provide Applicants with a normalized framework for ascribing cost to technology capital and operations in order to address primary technical target 3.1. Please see Section IV.D.9 of the FOA for further instructions on use of the REMOTE Calculator Tool.
- 3.2 Applicants should numerically justify how they will achieve this metric. “Process Energy Efficiency” should be calculated to include the primary energy of the inputs needed to drive the process. Here process heat and electricity should be derived from natural gas or otherwise justified. The low energy efficiency of existing metabolic pathways and required fast rates may result in lower system energy efficiency.
- 3.3 Applicants should numerically justify how they will achieve this metric. Calculations are detailed in Sec. I.F., Calcs 1, 4 and 5.

## F. SUPPLEMENTARY MATERIALS

**Table 1:** Enthalpy of formation, Entropy, Gibbs free energy of formation, and lower heating value of combustion for selected compounds at 298K, 1bar.<sup>29</sup>

Name	Molecular Formula	State	Molecular Weight	$\Delta H_f^\circ$ (kJ mol <sup>-1</sup> )	$S^\circ$ (J mol <sup>-1</sup> K <sup>-1</sup> )	$\Delta G_f^\circ$ (kJ mol <sup>-1</sup> )	$\Delta_c H^\circ_{LHV}$ (kJ mol <sup>-1</sup> )
Hydrogen	H <sub>2</sub>	Gas	2.02	-	130.7	-	-241.8
Water	H <sub>2</sub> O	Liquid	18.02	-285.8	70.0	-237.2	-
Water	H <sub>2</sub> O	Gas	18.02	-241.8	188.8	-228.5	-
Oxygen	O <sub>2</sub>	Gas	32.00	-	205.2	-	-

<sup>29</sup> "NIST Chemistry WebBook." 2011. National Institute of Standards and Technology. March 2013.  
<<http://webbook.nist.gov/chemistry/>>.



Graphite	C	Solid	12.01	-	5.6	-	-393.5
Methane	CH <sub>4</sub>	Gas	16.04	-74.5	186.3	-50.5	-802.6
Methanol	CH <sub>3</sub> OH	Liquid	32.04	-238.7	127.2	-166.4	-638.5
Formaldehyde	CH <sub>2</sub> O	Gas	30.03	-108.6	219.0	-102.7	-526.8
Formic Acid	CH <sub>2</sub> O <sub>2</sub>	Liquid	46.03	-425.0	131.8	-362.5	-254.2
Carbon Dioxide	CO <sub>2</sub>	Gas	44.01	-393.5	213.8	-394.4	-
Glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	Solid	180.16	-1271	209.2	-906.2	-2540.8
n-Butanol	C <sub>4</sub> H <sub>10</sub> O	Liquid	74.12	-328	225.7	-163.3	-2455.6
Ethanol	C <sub>2</sub> H <sub>6</sub> O	Liquid	46.07	-276	159.9	-172.9	-1235

**Table 2:** Thermodynamic, energy efficiency, and carbon yield calculations for selected metabolic pathways at 298K, 1bar, pH 7.<sup>29,30</sup>

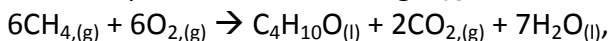
Pathway	$\Delta H^{\circ}$ (kJ mol <sub>rxn</sub> <sup>-1</sup> )	$T\Delta S^{\circ}$ (kJ mol <sub>rxn</sub> <sup>-1</sup> )	$\Delta G^{\circ}$ (kJ mol <sub>rxn</sub> <sup>-1</sup> )	Energy Efficiency*	Carbon Yield
1) C <sub>6</sub> H <sub>12</sub> O <sub>6(s)</sub> → 2C <sub>2</sub> H <sub>6</sub> O <sub>(l)</sub> + 2CO <sub>2(g)</sub>	-68	160	-228	97.2%	66.7%
2) 6CH <sub>4(g)</sub> + 6O <sub>2(g)</sub> → C <sub>4</sub> H <sub>10</sub> O <sub>(l)</sub> + 2CO <sub>2(g)</sub> + 7H <sub>2</sub> O <sub>(l)</sub>	-2669	-360	-2310	51.0%	66.7%
3) 4CH <sub>4(g)</sub> + 2O <sub>2(g)</sub> → C <sub>4</sub> H <sub>10</sub> O <sub>(l)</sub> + 3H <sub>2</sub> O <sub>(l)</sub>	-887	-215	-673	76.5%	100%
4) CH <sub>4(g)</sub> + O <sub>2(g)</sub> → CH <sub>2</sub> O <sub>(g)</sub> + H <sub>2</sub> O <sub>(l)</sub>	-320	-315	-289	65.6%	100%
5) 6CH <sub>2</sub> O <sub>(g)</sub> → C <sub>4</sub> H <sub>10</sub> O <sub>(l)</sub> + 2CO <sub>2(g)</sub> + H <sub>2</sub> O <sub>(l)</sub>	-749	-176	-573	77.7%	66.7%
6) 2CH <sub>4</sub> + O <sub>2</sub> → 2CH <sub>3</sub> OH	-328	-97	-232	80.0%	100%
7) 4CH <sub>3</sub> OH → C <sub>4</sub> H <sub>10</sub> O + 3H <sub>2</sub> O	-230	-21	-209	96.1%	100%
8) CH <sub>4(g)</sub> + O <sub>2(g)</sub> + NADH + H <sup>+</sup> → CH <sub>3</sub> OH <sub>(l)</sub> + H <sub>2</sub> O <sub>(l)</sub> + NAD <sup>+</sup>	Not available	Not available	-336	Not available	100%
9) 6CH <sub>3</sub> OH + 6NAD <sup>+</sup> + 2ADP + 2P <sub>i</sub> → C <sub>4</sub> H <sub>10</sub> O + 2CO <sub>2</sub> + 3H <sub>2</sub> O + 2ATP + 6NADH + 8H <sup>+</sup>	Not available	Not available	Not available	64.1% <sup>†</sup>	66.7%

\*Energy efficiency is calculated from the lower heating value (LHV) of combustion of products divided by the LHV of the reactants.

<sup>†</sup> Energy efficiency is calculated considering only the n-butanol product and the methanol reactant.

### Calculation 1 – Required Gas Transfer Coefficient<sup>31</sup>

To achieve a production rate of 2 g<sub>n-BuOH</sub>/L/hr and using metabolism as follows:



requires 2.6 g<sub>CH<sub>4</sub></sub>/L/hr and 5.2 g<sub>O<sub>2</sub></sub>/L/hr feed into the reactor.

To define the required  $k_L a$  for CH<sub>4</sub> and O<sub>2</sub>:

$$dC_i/dt = k_L a \times (C_i^* - C_{0,i})$$

$C_i^* = k_H \times p_i \times T$ , and is the gas solubility of species,  $i$

$k_H$  is defined as the Henry's Law constant

$p_i$  is defined as the partial pressure of the species,  $i$

$C_{0,i}$  is defined as the effective gas concentration of species,  $i$

To calculate  $k_L a$  for a 1:1 ratio of CH<sub>4</sub>:O<sub>2</sub> at 298K, 1atm in aqueous solution:

$$k_H, \text{CH}_4 = 0.0014 \text{ mol kg}^{-1} \text{ bar}^{-1}, p_{\text{CH}_4} = 0.493 \text{ bar}, T = 298\text{K}, \rho_{\text{H}_2\text{O}} = 0.997 \text{ kg/L}, C_{0,i} = 0.2 C_{\text{CH}_4}^*$$

<sup>30</sup> G. Karp, *Cell and Molecular Biology* (Wiley, 2008).

<sup>31</sup> "NIST Chemistry WebBook." 2011. National Institute of Standards and Technology. March 2013.

<<http://webbook.nist.gov/chemistry/>>.

$$k^{\circ}_{H,O_2} = 0.0013 \text{ mol kg}^{-1} \text{ bar}^{-1}, p_{O_2} = 0.493 \text{ bar}, T = 298\text{K}, \rho_{H_2O} = 0.997 \text{ kg/L}, C_{O,i} = 0.2 C^*_{O_2}$$

To calculate the minimum required  $k_1a$ :

$$k_1a_{CH_4} > 300 \text{ hr}^{-1}$$

$$k_1a_{O_2} > 320 \text{ hr}^{-1}$$

To calculate  $k_1a$  for a 1:1:4 ratio of  $CH_4:O_2:N_2$  at 298K, 1atm in aqueous solution:

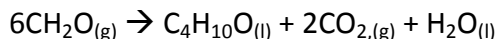
$$p_{CH_4} = 0.165 \text{ bar}, p_{O_2} = 0.165 \text{ bar}$$

$$k_1a_{CH_4} > 900 \text{ hr}^{-1}$$

$$k_1a_{O_2} > 950 \text{ hr}^{-1}$$

## Calculation 2 – Energy Efficiency and Carbon Yield

Starting with the following metabolic pathway, the energy efficiency is calculated by:



$$\text{Energy Efficiency} = \Delta H^{\circ}_{C,LHV, Products} / \Delta H^{\circ}_{C,LHV, Reactants}$$

$$= (1 \text{ mol}_{n\text{-BuOH}} \times 2455.6 \text{ kJ/mol}_{n\text{-BuOH}}) / (6 \text{ mol}_{CH_2O} \times 526.8 \text{ kJ/mol}_{CH_2O})$$

$$= \mathbf{77.7\% \text{ Energy Efficiency}}$$

Similarly, the carbon yield to the final fuel molecule can be calculated using the same pathway:

$$\text{Carbon Yield} = (\# \text{ carbon atoms in product}) / (\# \text{ of carbon atoms in reactant})$$

$$= (1 \text{ mol}_{n\text{-BuOH}} \times 4 \text{ mol}_C/\text{mol}_{n\text{-BuOH}}) / (6 \text{ mol}_{CH_2O} \times 1 \text{ mol}_C/\text{mol}_{CH_2O}) = \mathbf{66.7\% \text{ Carbon Yield}}$$

Note that the  $CO_2$  product is not part of the final fuel and so is not included in carbon yield calculations. Similarly, if biomass is produced in route towards liquid fuel production the cell biomass should not be considered as a final product. Therefore, biomass should not be included in energy efficiency and carbon yield calculations.

## Calculation 3 – Catalyst Loading

Required protein activating concentration:

$$(1 \text{ g}_{CH_4}/\text{L}/\text{hr}) \times (1 \text{ mol}_{CH_4}/16.04 \text{ g}_{CH_4}) \times (1 \text{ hr}/3600 \text{ s}) / (10 \text{ mol}_{CH_4}/\text{s}/\text{mol}_{\text{enzyme}})$$

$$= \mathbf{0.17 \text{ }\mu\text{M}}$$

If molecular weight of activating protein is 100,000 g/mol, then 0.17 g<sub>protein</sub>/L<sub>reactor</sub> is required.

#### Calculation 4 – System Productivity

To create a system sized to a standard shipping container (20' × 8' × 8') that produces 50 BPD of product:

$$\begin{aligned} & (50 \text{ BPD} / 1280 \text{ ft}^3) \times (1 \text{ ft}^3 / 28.32 \text{ L}) \times (6.12 \times 10^9 \text{ J/boe}) \times (1000 \text{ g}_{\text{n-BuOH}} / 33.1 \times 10^6 \text{ J}) \\ & \times (1 \text{ day} / 24 \text{ hrs}) \\ & = \mathbf{10.6 \text{ g}_{\text{n-BuOH}} / \text{L/hr}} \end{aligned}$$

#### Calculation 5 – Heat Removal Rate

For a reactor with 25 g<sub>n-BuOH</sub>/L/hr production rate and 35% metabolic energy efficiency, the heat removal rate can be calculated as follows:

$$\begin{aligned} & 8.7\text{CH}_4 + 8.8\text{O}_2 \rightarrow \text{C}_4\text{H}_{10}\text{O} + 2.2\text{CH}_{1.75}\text{O}_{0.46} + 2.5\text{CO}_2 + 10.5\text{H}_2\text{O} \quad \Delta H^\circ = -3863 \text{ kJ/mol}_{\text{n-BuOH}} \\ & \text{CH}_{1.75}\text{O}_{0.46} \text{ is defined here as the molecular formula for a biocatalyst with } \Delta H_f^\circ = -91.3 \text{ kJ/mol} \\ & E_{\text{eff}} = (2455.6 \text{ kJ/mol}_{\text{n-BuOH}}) \times (1 \text{ mol}_{\text{n-BuOH}} / 8.7 \text{ mol}_{\text{CH}_4}) \times (1 \text{ mol}_{\text{CH}_4} / 802.6 \text{ kJ}) = 35\% \\ & (25 \text{ g}_{\text{n-BuOH}} / \text{L/hr}) \times (1 \text{ mol}_{\text{n-BuOH}} / 74.12 \text{ g}_{\text{n-BuOH}}) \times (3863 \text{ kJ/mol}_{\text{n-BuOH}}) \times (1 \text{ hr} / 3600 \text{ s}) \\ & \times (1000 \text{ L/m}^3) = \mathbf{362 \text{ kW/m}^3} \end{aligned}$$

#### G. APPLICATIONS SPECIFICALLY NOT OF INTEREST

The following types of applications will be deemed nonresponsive and will not be reviewed or considered (see Section III.C.2 of the FOA):

- Applications that fall outside the technical parameters specified in the FOA, including but not limited to:
  - Non-enzymatic routes to produce syngas
  - Fuel synthesis pathways that use syngas or CO<sub>2</sub> and H<sub>2</sub> as starting reactants
  - Purely non-biological approaches for methane conversion to liquid fuels
  - Production of hydrocarbon compounds that are neither fuel molecules or fuel molecule precursors, or exist primarily in the gas phase at STP
  - Biological approaches that rely on the accumulation of cell biomass as an intermediate to fuel production.
- Applications that were already submitted to pending ARPA-E FOAs.
- Applications that are not scientifically distinct from applications submitted to pending ARPA-E FOAs.
- Applications for basic research aimed at discovery and fundamental knowledge generation.

- Applications for large-scale demonstration projects of existing technologies.
- Applications for proposed technologies that represent incremental improvements to existing technologies.
- Applications for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Applications that do not address at least one of ARPA-E's Mission Areas (see Section I.A of the FOA).
- Applications for proposed technologies that are not transformational, as described in Section I.A of the FOA. Transformational, as illustrated in Figure 1 in Section I.A of the FOA, is the promise of high payoff in some sector of the energy economy.
- Applications 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 (see Figure 1 in Section I.A of the FOA).
- Applications that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.

## II. AWARD INFORMATION

### A. AWARD OVERVIEW

ARPA-E expects to make approximately ~~\$20~~ \$30 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 8-12 awards under this FOA. ARPA-E may issue one, multiple, or no awards.

Individual awards may vary between approximately \$250,000 and \$10 million. ARPA-E will provide support at the upper ranges only for applications with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be ~~10/01/2013~~ 11/01/2013, or as negotiated.

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

ARPA-E may issue awards in one or both of the following funding categories: "Proof-of-Concept Seedling Project" and "Technology Development Project."

- **Proof-of-Concept Seedling Project:** Proof-of-Concept Seedlings are projects which range between \$250,000 and \$1 million and have a period of performance of no more than a year. If both of these criteria are not met, the project is a Technology Development Project. Seedling projects typically focus on early-stage, proof-of-concept level R&D efforts. Applicants should submit evidence of an idea, described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. ARPA-E may issue approximately 2-4 awards in this category, with an average award amount of \$500,000.
- **Technology Development Project:** Awards that either range between \$1 million and \$10 million, have a period of performance longer than one year, or both are Technology Development Projects. These projects typically focus on early-stage prototypes of various technology concepts for which some kind of initial proof-of-concept component demonstration already exists. Applicants should submit concrete data that supports the success of the proposed project. ARPA-E may issue approximately 6-8 awards in this category, with an average award amount of \$3 million.

ARPA-E may establish more than one budget period for each award and fund only the initial budget period(s). Applicants are not guaranteed funding beyond the initial budget period(s). Before the expiration of the initial budget period(s), ARPA-E may perform a down-select among different recipients and provide additional funding only to a subset of recipients.

## **B. ARPA-E FUNDING AGREEMENTS**

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."<sup>32</sup> Accordingly, ARPA-E has substantial involvement in the direction of every project, as described in Section II.C below.

### **1. COOPERATIVE AGREEMENTS**

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.<sup>33</sup>

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

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

### **2. FUNDING AGREEMENTS WITH FFRDCs, GOGOs, AND FEDERAL INSTRUMENTALITIES<sup>34</sup>**

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

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

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<sup>32</sup> U.S. Congress, Conference Report to accompany the 21<sup>st</sup> Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

<sup>33</sup> The Prime Recipient is the signatory to the funding agreement with ARPA-E.

<sup>34</sup> DOE/NNSA GOGOs are not eligible to apply for funding, as described in Section III.A of the FOA.

When a FFRDC or non-DOE/NNSA GOGO is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC or non-DOE/NNSA GOGO 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 or non-DOE/NNSA GOGO 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, and Federal instrumentalities (e.g., Tennessee Valley Authority) generally take the form of Interagency Agreements. Any funding agreement with a FFRDC or non-DOE/NNSA GOGO will have substantially similar terms and conditions as ARPA-E's Model Cooperative Agreement (<http://arpa-e.energy.gov/?q=project-guidance/award>).

### **3. TECHNOLOGY INVESTMENT AGREEMENTS**

ARPA-E may use its “other transactions” authority under the America COMPETES Reauthorization Act of 2010 or DOE’s “other transactions” authority under the Energy Policy Act of 2005 to enter into Technology Investment Agreements (TIAs) with Prime Recipients. ARPA-E may negotiate a TIA when it determines that the use of a standard cooperative agreement, grant, or contract is not feasible or appropriate for a project.

A TIA is more flexible than a traditional financial assistance agreement. In using a TIA, ARPA-E may modify standard Government terms and conditions.

If Applicants are seeking to negotiate a TIA, they are required to include an explicit request in their Full Applications. Please refer to the Business Assurances Form for guidance on the content and form of the request.

In general, TIAs require a cost share of 50%. See Section III.B.2 of the FOA.

### **4. GRANTS**

Although ARPA-E has the authority to provide financial support to Prime Recipients through Grants, ARPA-E generally does not fund projects through Grants. ARPA-E may fund a limited number of projects through Grants, as appropriate.

### C. **STATEMENT OF SUBSTANTIAL INVOLVEMENT**

Generally, ARPA-E is substantially involved in the direction of projects (regardless of the type of funding agreement) from inception to completion. For the purposes of an ARPA-E project, substantial involvement means:

- ARPA-E does not limit its involvement to the administrative requirements of the ARPA-E funding agreement. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole. Project teams must adhere to ARPA-E technical direction and comply with agency-specific and programmatic requirements.
- ARPA-E may intervene at any time to address the conduct or performance of project activities.
- During award negotiations, ARPA-E Program Directors establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. Prime Recipients document the achievement of these milestones and deliverables in quarterly technical and financial progress reports, which are reviewed and evaluated by ARPA-E Program Directors (see Attachment 4 to ARPA-E's Model Cooperative Agreement, available at <http://arpa-e.energy.gov/?q=project-guidance/award>). ARPA-E Program Directors visit each Prime Recipient at least twice per year, and hold periodic meetings, conference calls, and webinars with Project Teams. ARPA-E Program Directors may modify or terminate projects that fail to achieve predetermined technical milestones and deliverables.
- ARPA-E reviews reimbursement requests for compliance with applicable Federal cost principles and Prime Recipients' cost share obligations.<sup>35</sup> Upon request, Prime Recipients are required to provide additional information and documentation to support claimed expenditures. Prime Recipients are required to comply with agency-specific and programmatic requirements. Please refer to Section VI.B.3-4 of the FOA for guidance on proof of cost share commitment and cost share reporting.
- ARPA-E works closely with Prime Recipients to facilitate and expedite the deployment of ARPA-E-funded technologies to market. ARPA-E works with other Government agencies and nonprofits to provide mentoring and networking

<sup>35</sup> To request reimbursement, Prime Recipients must submit: (1) a Standard Form (SF) 270 ("Request for Advance or Reimbursement"); (2) a "Reimbursement Request Spreadsheet," which must contain the information shown in Appendix B to Attachment 1 of ARPA-E's Model Cooperative Agreement (<http://arpa-e.energy.gov/?q=project-guidance/award>); and (3) supporting documentation, which may consist of summary information (e.g., printouts from internal financial systems) or detailed documentation (e.g., invoices on appropriate letterhead, time cards, travel vouchers). The supporting documentation must show the method by which the Prime Recipient calculated the total Federal share and non-Federal cost share.



opportunities for Prime Recipients. ARPA-E also organizes and sponsors events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E establishes collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

- ARPA-E may fund some projects on a fixed-obligation basis.

### **III. ELIGIBILITY INFORMATION**

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

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

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,<sup>36</sup> as the lead for a Project Team,<sup>37</sup> or as a member of a Project Team.

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

For-profit entities, educational institutions, and nonprofits<sup>38</sup> that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

FFRDCs are eligible to apply for funding as the lead organization for a Project Team or as a member of a Project Team, but not as a Standalone Applicant.

DOE/NNSA GOGOs are not eligible to apply for funding.

Non-DOE/NNSA GOGOs 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.

State and local 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. All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the

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<sup>36</sup> A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.

<sup>37</sup> The term "Project Team" is used to mean any entity with multiple players working collaboratively and could encompass anything from an existing organization to an ad hoc teaming arrangement. A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

<sup>38</sup> Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

United States (including U.S. territories). The Applicant may request a waiver of this requirement in the Business Assurances Form, which is submitted with the Full Application. Please refer to the Business Assurances 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 DOE Contracting Officer ([ARPA-E-CO@hq.doe.gov](mailto:ARPA-E-CO@hq.doe.gov)).

Unincorporated consortia must provide the Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This agreement binds the individual consortium members together and should discuss, among other things, 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 OR MATCHING<sup>39</sup>**

Applicants are bound by the cost share proposed in their Full Applications. In the Business Assurances Form accompanying the Full Application, Applicants must provide written assurance of their cost share commitments. Please refer to the Business Assurances Form available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>) for additional guidance.

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

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<sup>39</sup> Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement, the Prime Recipient must provide at least 20% of the Total Project Cost<sup>40</sup> as cost share, except as provided in Sections III.B.2 or III.B.3 below.<sup>41</sup>

## **2. INCREASED COST SHARE REQUIREMENT**

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

The Prime Recipient may request the use of a Technology Investment Agreement (instead of a Cooperative Agreement) in the Business Assurances Form submitted with the Full Application (see Section II.B.3 of the FOA). Under a Technology Investment Agreement, the Prime Recipient must provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this minimum cost share requirement, as appropriate.

## **3. REDUCED COST SHARE REQUIREMENT**

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

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is required to provide at least 5% of the Total Project Cost as cost share.
- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs are required to provide at least 5% of the Total Project Cost as cost share.
- Project Teams where domestic educational institutions, domestic nonprofits, and/or FFRDCs perform greater than or equal to 80%, but less than 100%, 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 minimum cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

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<sup>40</sup> The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by **GOGOs**, FFRDCs, and GOCOs.

<sup>41</sup> Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

#### **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 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 project period, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination. ARPA-E requires all recipients to contribute cost share in proportion with each submitted invoice over the life of the program.

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.1 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 project period;
- Proceeds from the prospective sale of an asset of an activity;

- Federal funding or property (e.g., Federal grants, equipment owned by the Federal Government); or
- Expenditures that were reimbursed under a separate Federal program.

In addition, Project Teams may not use independent research and development (IR&D) funds to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment 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 DOE Contracting Officer and incorporated into the project budget before the expenditures are incurred.

Applicants may wish to refer to 10 C.F.R. parts 600 and 603 for additional guidance on cost sharing, specifically 10 C.F.R. §§ 600.30, 600.123, 600.224, 600.313, and 603.525-555.

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

Because FFRDCs and GOGOs are funded by the Federal Government, costs incurred by FFRDCs and GOGOs 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.

## **8. COST SHARE VERIFICATION**

Applicants are required to provide written assurance of their proposed cost share contributions in their Full Applications. Please refer to the Business Assurances Form for guidance on the cost share information that must be included.

Upon selection for award negotiations, Applicants are required to provide additional 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.

ARPA-E will 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, such as the funding category (see Section II.A of the FOA). 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.

ARPA-E will 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 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:

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

- The Applicant successfully uploaded all required documents to ARPA-E eXCHANGE by the deadline stated in 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. Any “Applications Specifically Not of Interest,” as described in Section I.G of the FOA, are deemed nonresponsive and are not reviewed or considered.

## **3. LIMITATION ON NUMBER OF APPLICATIONS**

ARPA-E is not limiting the number of applications that may be submitted by 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. 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 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 30 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. ARPA-E reviews only compliant and responsive Full Applications.

#### **4. REPLY TO REVIEWER COMMENTS**

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

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 noncompliant.

## **5. “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, perform a “down-select” of Full Applications. Through a down-select, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, 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 and site visits, nor will these costs be eligible for reimbursement as pre-award costs.

ARPA-E may select applications for funding 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. ARPA-E may select or not select a Full Application for award negotiations. ARPA-E 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.

## 7. MANDATORY WEBINAR

All selected Applicants, including the Principal Investigator and the financial manager for the project, are required to participate in a webinar that is held within approximately one week of the selection notification. During the webinar, ARPA-E officials present important information on the award negotiation process, including deadlines for the completion of certain actions.

### B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>), including the SF-424, Budget Justification Workbook/SF-424A, Business Assurances Form, and Other Sources of Funding Disclosure Form. Sample responses to the Other Sources of Funding Disclosure Form and Business Assurances Form, and a sample Summary Slide, are also available on ARPA-E eXCHANGE. Applicants must 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 Technical Milestones section of and Deliverables – Instructions and Examples, the template for the Summary Slide, the template, and for the Summary for Public Release, the template for the REMOTE Calculator Tool (for Category 3 Full Applications), and the template for the Reply to Reviewer Comments template.

### 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 requirements:

- 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. Use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The Control Number 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.

ARPA-E will not review or consider noncompliant and/or nonresponsive Concept Papers (see Section III.C of the FOA).

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

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

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

SECTION	PAGE LIMIT	DESCRIPTION
<b>Technology Description</b>	2 pages maximum	<ul style="list-style-type: none"> <li>Applicants are required to describe succinctly: <ul style="list-style-type: none"> <li>The proposed technology, including its basic operating principles and how it is unique and innovative;</li> <li>The proposed technology's target level of performance (Applicants should provide technical data or other support to show how the proposed target could be met);</li> <li>The current state-of-the-art in the relevant field and application, including key shortcomings, limitations, and challenges;</li> <li>How the proposed technology will overcome the shortcomings, limitations, and challenges in the relevant field and application;</li> <li>The potential impact that the proposed project would have on the relevant field and application;</li> <li>The key technical risks/issues associated with the proposed technology development plan; and</li> <li>The impact that ARPA-E funding would have on the proposed project.</li> </ul> </li> </ul>
<b>Addendum</b>	2 pages maximum	<ul style="list-style-type: none"> <li>Applicants must state whether the proposed budget for their project falls into the first or second funding category below: <ol style="list-style-type: none"> <li>Proof-of-Concept Seedling Project: \$250,000 - \$999,999.99 and period of performance of 12 months or less; or</li> <li>Technology Development Project: \$1 million - \$10 million or a period of performance of greater than 12 months.</li> </ol> </li> <li>Applicants may provide graphs, charts, or other data to supplement their Technology Description.</li> <li>Applicants are required to describe succinctly the qualifications, experience, and capabilities of the proposed Project Team, including: <ul style="list-style-type: none"> <li>Whether the Principal Investigator (PI) and Project Team have the skill and expertise needed to successfully execute the project plan;</li> <li>Whether the Applicant has prior experience which demonstrates an ability to perform R&amp;D tasks of similar risk and complexity;</li> <li>Whether the Applicant has worked together with its teaming partners on prior projects or programs; and</li> <li>Whether the Applicant has adequate access to equipment and facilities necessary to accomplish the R&amp;D effort and/or clearly</li> </ul> </li> </ul>

		explain how it intends to obtain access to necessary equipment and facilities.
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#### D. CONTENT AND FORM OF FULL APPLICATIONS

~~[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]~~

Full Applications must conform to the following requirements:

- Each document must be submitted in the file format prescribed below.
- All Full Applications 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. Use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The Control Number 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.

ARPA-E will not review or consider noncompliant and/or nonresponsive Full Applications (see Section III.C of the FOA).

Each Full Application should be limited to a single concept or technology. Unrelated concepts and technologies should not be consolidated in a single Full Application.

Component	Required Format	Description and Information
Technical Volume	PDF	The centerpiece of the Full Application. Provides a detailed description of the proposed R&D project and Project Team. Applicants must complete the Technical Volume template available on ARPA-E eXCHANGE ( <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> ).
SF-424	PDF	Application for Federal Assistance ( <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> )
Budget Justification Workbook/SF-424A	XLS	Budget Information – Non-Construction Programs ( <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> )
Technical Milestones and Deliverables	PDF	Applicants must use the Technical Milestones and Deliverables – Instructions and Examples available on ARPA-E eXCHANGE ( <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> ) for the Technical Milestones and Deliverables.
Summary for Public Release	PDF	Short summary of the proposed R&D project. Intended for public release. Applicants must complete the Summary for Public Release template available on ARPA-E eXCHANGE ( <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> ).
Summary Slide	PPT	A four-panel project slide summarizing different aspects of the proposed R&D

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Problems with ARPA-E eXCHANGE? Email [ExchangeHelp@hq.doe.gov](mailto:ExchangeHelp@hq.doe.gov) (with FOA name and number in subject line).

		project. Applicants must complete the Summary Slide template available on ARPA-E eXCHANGE ( <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> ). A sample Summary Slide is also available on ARPA-E eXCHANGE.
<b>Business Assurances Form</b>	PDF	Requires the Applicant to disclose potential improprieties, potential conflicts of interest within the Project Team, and written assurance of its cost share commitment. If the Applicant is a FFRDC, requires the Applicant to provide written authorization from the cognizant Federal agency and, if a DOE/NNSA FFRDC, a Field Work Proposal. Allows the Applicant to request a modification or waiver of the Performance of Work in the United States requirement, the Technology Transfer & Outreach (TT&O) spending requirement, and/or the U.S. manufacturing requirement. In addition, allows the Applicant to request the use of a Technology Investment Agreement. This form is available on ARPA-E eXCHANGE at <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> . A sample response to the Business Assurances Form is also available on ARPA-E eXCHANGE.
<b>Other Sources of Funding Disclosure form</b>	PDF	Requires the PI to describe the additionality and risks associated with the proposed project, disclose financial assistance from Federal entities, disclose funding from non-Federal entities for related work, and provide letters or other communications from private investors explaining why they decided not to fund the proposed R&D project. This form is available on ARPA-E eXCHANGE at <a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a> . A sample response to the Other Sources of Funding Disclosure Form is also available on ARPA-E eXCHANGE.
<b>REMOTE Calculator Tool</b>	XLS	<p>Full Application Category 3 Applicants are required to submit a completed REMOTE Calculator Tool. Category 3 Applicants may access the REMOTE Calculator Tool template in ARPA-E eXCHANGE(<a href="https://arpa-e-foa.energy.gov">https://arpa-e-foa.energy.gov</a>).</p> <p>The purpose of the REMOTE Calculator Tool template is to provide Applicants with a normalized framework for ascribing cost to technology capital and operations in order to address primary technical target 3.1 ("Overall Process CapEx"). Applicants' responses in the REMOTE Calculator Tool will be evaluated and reviewed by ARPA-E as part of the Applicants' Full Application.</p>

ARPA-E provides detailed guidance on the content and form of each component below.

## 1. FIRST COMPONENT: TECHNICAL VOLUME

The Technical Volume must be submitted in Adobe PDF format. A Technical Volume template is available at <https://arpa-e-foa.energy.gov>. The Technical Volume must conform to the following content and form requirements, including maximum page lengths. If Applicants exceed the maximum page lengths indicated below, ARPA-E will review only the authorized number of pages and disregard any additional pages.

Applicants must provide sufficient citations and references to the primary research literature to justify the claims and approaches made in the Technical Volume. ARPA-E and reviewers may review primary research literature in order to evaluate applications. However, ARPA-E and reviewers are under no obligation to review cited sources (e.g., Internet websites).

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

<b>SECTION</b>	<b>PAGE LIMIT</b>	<b>DESCRIPTION</b>
<b>Technical Approach</b>	1 page max.	<ul style="list-style-type: none"> <li>• Provide a concise summary of the proposed R&amp;D project. The summary should be written for a technically literate, but non-specialist, audience.</li> </ul>
<b>R&amp;D Tasks</b>	1 page max.	<ul style="list-style-type: none"> <li>• Describe succinctly: <ul style="list-style-type: none"> <li>○ the purpose of the proposed R&amp;D project,</li> <li>○ the underlying hypothesis(es)/technical concept(s) guiding the approach, and</li> <li>○ a list of the tasks the research team will undertake and accomplish to achieve this purpose.</li> </ul> </li> </ul>
<b>R&amp;D Strategy</b>	20 pages max.	<ul style="list-style-type: none"> <li>• Applicants are <u>required</u> to describe each of the following aspects of their proposal. Applicants should present supporting references, data, calculations, estimates, and/or projections to justify each set of claims, explicitly stating any variables and assumptions. <ul style="list-style-type: none"> <li>○ <u>Innovation and Impact</u> – Describe and justify: <ul style="list-style-type: none"> <li>▪ the performance of current state-of-the-art technology solutions in the application area addressed,</li> <li>▪ how the proposed solution is a departure from currently available technology and differs from others under investigation in the field,</li> <li>▪ the performance of the proposed solution, and the extent to which it represents a significant advance relative to the state of the art,</li> <li>▪ the impact of the proposed solution on system-level performance metrics, including justification for any adverse effects on system performance,</li> <li>▪ how the anticipated cost of the proposed solution compares with currently available technology, and the extent to which the solution can achieve a disruptive cost-performance learning curve relative to the state of the art</li> <li>▪ the extent to which the technology benefits, if realized, will translate into substantial impact on one or more ARPA-E mission areas.</li> </ul> </li> <li>○ <u>Feasibility</u> – Describe and justify: <ul style="list-style-type: none"> <li>▪ the feasibility of the proposed technology solution, and capability of achieving the cost and performance targets at scale (i.e. large-volume/high-throughput scenario)</li> </ul> </li> <li>○ <u>Performance Team</u> – Describe succinctly: <ul style="list-style-type: none"> <li>▪ the members of the proposed research team, and</li> <li>▪ why the proposed team is uniquely qualified to carry out the proposed research. Synopses of past research accomplishments are insufficient to demonstrate that a team is “uniquely qualified.” Applicants are required to identify the unique combination of training and experience that make the proposed team uniquely qualified to successfully execute the</li> </ul> </li> </ul> </li> </ul>

		proposed project. Preference will be given to multidisciplinary teams where different Project Team members complement each other and have expertise in different aspects of the technology.
<b>Technology-to-Market Strategy</b>	2 pages max.	<ul style="list-style-type: none"> <li>• ARPA-E supports energy technology R&amp;D projects for a limited period of time at critical high-risk points in the technology development cycle. ARPA-E technologies <i>are not required</i> to achieve commercial deployment by the end of the project period; however, funded projects must be on a reasonable path toward making substantive impact on ARPA-E's mission areas through commercial adoption and eventual wide-scale market deployment. If known, please describe: <ul style="list-style-type: none"> <li>○ How the proposed technology is expected to transition from the lab to deployment and adoption. Please include: description of the expected product, potential near-term and long-term markets of entry, likely commercialization approach (startup, license, etc.), specific organizations expected to be involved in the transition of the technology (partners, customers, etc.), expected timeline for commercialization;</li> <li>○ Manufacturing and scalability risks associated with technology;</li> <li>○ Resource needs for the next phase of development that follows the end of the ARPA-E project; and</li> <li>○ why the proposed research is not being pursued by industry today.</li> </ul> </li> </ul>
<b>Budget Summary</b>	2 pages max.	<ul style="list-style-type: none"> <li>• Applicants are required to provide a two-page budget summary, broken down by milestones. The summaries must conform to the following guidelines: <ul style="list-style-type: none"> <li>○ The budget summary should be clearly associated with the milestones outlined as part of the Technical R&amp;D Plan and reflect quarterly progress on the proposed project.</li> <li>○ All major equipment purchases must be included in the budget summary. For equipment acquired as part of the proposed R&amp;D project, state the proposed disposition of the equipment after the project's completion. Specifically, state if the useful life of the equipment will correlate with its authorized purpose under the proposed project.</li> <li>○ If costs are less than would normally be expected due to large amounts of previous R&amp;D work done by one or more members of the research team, please describe and explain accordingly.</li> <li>○ Applicants are required to estimate the potential materials and manufacturing costs of the proposed technology to justify the technology's potential to approach, meet, or exceed the cost targets given in each FOA. In making these estimations, Applicants must describe the manufacturing approaches that will most likely scale up the proposed technologies.</li> </ul> </li> </ul>
<b>Qualifications, Experience, and</b>	For each PQS, 3	<ul style="list-style-type: none"> <li>• Applicants are required to provide a Personal Qualification Summary (PQS) for the PI and each Key Participant.<sup>42</sup> Each PQS is limited to 3 pages maximum. Curriculum vitae will not be considered. Each PQS must include:</li> </ul>

<sup>42</sup> A Key Participant is any individual who would contribute in a substantive, measurable way to the execution of the proposed project.



<b>Capabilities</b>	pages max.	<ul style="list-style-type: none"> <li>Education/training,</li> <li>Employment history,</li> <li>Awards and honors,</li> <li>Up to 10 peer-reviewed publications specifically related to the proposed R&amp;D project,</li> <li>Up to 10 other peer-reviewed publications demonstrating capabilities in the broad field, and</li> <li>Up to 10 non-peer reviewed publications and patents demonstrating capabilities in the broad field.</li> </ul>
<b>Participating Organizations</b>	1 page max.	<ul style="list-style-type: none"> <li>Describe succinctly why each proposed organization is qualified to accomplish their portion of the proposed R&amp;D project. Please describe the Project Team's unique qualifications, expertise, equipment, or facilities that will facilitate the successful completion of the proposed project.</li> </ul>
<b>Prior Collaboration</b>	1 page max.	<ul style="list-style-type: none"> <li>Describe succinctly: <ul style="list-style-type: none"> <li>any prior projects, programs, and initiatives on which the Project Team has collaborated;</li> <li>the roles of each Project Team member in the project, program, or initiative;</li> <li>whether the project, program, or initiative was ultimately successful; and</li> <li>any management, intellectual property, or other issues that arose within the Project Team and how they were resolved.</li> </ul> </li> </ul>
<b>Management Plan</b>	1 page max.	<ul style="list-style-type: none"> <li>An effective management plan is essential to ensure continuous effective communication between performance members. Describe succinctly: <ul style="list-style-type: none"> <li>the roles of each Project Team member;</li> <li>any critical handoffs/interdependencies between Project Team members;</li> <li>the technical (i.e., decision-making based on technical understanding of the problem) and management (i.e., monitoring different elements of the project and technology to ensure that it is well-integrated) aspects of the Management Plan and the role of the PI.</li> </ul> </li> </ul>
<b>Multi-Investigator Projects</b>	2 pages max.	<ul style="list-style-type: none"> <li>Roles of Participants: For multi-organizational or multi-investigator projects, describe succinctly: <ul style="list-style-type: none"> <li>the roles and the work to be performed by each PI and Key Participant;</li> <li>business agreements between the Applicant and each PI and Key Participant; and</li> <li>how the various efforts will be integrated and managed.</li> </ul> </li> <li>Multiple PIs: Standalone Applicants and Project Teams are required to disclose if the project will include multiple PIs. If multiple PIs will be designated, identify the Contact PI/Project Coordinator, and provide a "Coordination and Management Plan" that describes the organization structure of the project as it pertains to the designation of multiple PIs. This plan should include: <ul style="list-style-type: none"> <li>process for making decisions on scientific/technical direction;</li> <li>publication arrangements;</li> <li>intellectual property issues;</li> <li>communication plans;</li> </ul> </li> </ul>

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

		<ul style="list-style-type: none"> <li>o procedures for resolving conflicts; and</li> <li>o Pls' roles and administrative, technical, and scientific responsibilities for the project.</li> </ul>
<b>Intellectual Property Strategy</b>	No page limit	<ul style="list-style-type: none"> <li>• Describe specifically: <ul style="list-style-type: none"> <li>o existing intellectual property that will be used to develop the new intellectual property;</li> <li>o new intellectual property and data that will be created as part of this effort;</li> <li>o how the intellectual property strategy will increase the probability that the proposed transformational technology will reach the market and widely penetrate the installed base; and</li> <li>o the plan for disposition/ownership of the intellectual property, including intellectual property agreements or memorandums of understanding between Project Team members.</li> </ul> </li> </ul>

## 2. SECOND COMPONENT: SF-424

The SF-424 must be submitted in Adobe PDF format. This form is available on ARPA-E eXCHANGE at <https://arpa-e-foa.energy.gov>.

The SF-424 includes instructions for completing the form. Applicants are required to complete all required fields in accordance with the instructions.

Prime Recipients and Subrecipients are required to complete SF-LLL (Disclosure of Lobbying Activities), available at <http://www.whitehouse.gov/sites/default/files/omb/grants/sfillin.pdf>, if any non-Federal funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any Federal agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with your application or funding agreement. The completed SF-LLL must be appended to the SF-424.

ARPA-E provides the following supplemental guidance on completing the SF-424:

- Each Project Team should submit only one SF-424 (i.e., a Subrecipient should not submit a separate SF-424).
- Assume a project start date of 11/01/2013, or as negotiated.
- The list of certifications and assurances in Block 21 can be found at <http://energy.gov/management/downloads/certifications-and-assurances-use-sf-424>.

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

- The dates and dollar amounts on the SF-424 are for the entire project period (from the project start date to the project end date), not a portion thereof.

### **3. THIRD COMPONENT: BUDGET JUSTIFICATION WORKBOOK/SF-424A**

Applicants are required to complete the Budget Justification Workbook/SF-424A Excel spreadsheet. This form is available on ARPA-E eXCHANGE at <https://arpa-e-foa.energy.gov>. Prime Recipients must complete each tab of the Budget Justification Workbook for the project as a whole, including all work to be performed by the Prime Recipient and its Subrecipients and Contractors, and provide all requested documentation (e.g., a Federally-approved forward pricing rate agreement, Defense Contract Audit Agency or Government Audits and Reports, if available). The SF-424A form included with the Budget Justification Workbook will “auto-populate” as the Applicant enters information into the Workbook. Applicants must carefully read the “Instructions and Summary” tab provided within the Budget Justification Workbook.

Subrecipient information must be submitted as follows:

- Each Subrecipient incurring greater than or equal to 10% of the Total Project Cost must complete a separate Budget Justification workbook to justify its proposed budget. These worksheets must be inserted as additional sheets within in the Prime Recipient’s Budget Justification.
- Subrecipients incurring less than 10% of the Total Project Cost are not required to complete a separate Budget Justification workbook. However, such Subrecipients are required to provide supporting documentation to justify their proposed budgets. At a minimum, the supporting documentation must show which tasks/subtasks are being performed, the purpose/need for the effort, and a sufficient basis for the estimated costs.

ARPA-E provides the following supplemental guidance on completing the Budget Justification Workbook/SF-424A:

- Applicants may request funds under the appropriate object class category tabs as long as the item and amount requested are necessary to perform the proposed work, meet all the criteria for allowability under the applicable Federal cost principles, and are not prohibited by the funding restrictions described herein.
- If Patent costs are requested, they must be included in the Applicant’s proposed budget (see Section IV.G.3 of the FOA for more information on Patent Costs).

- Unless a waiver is granted by the Contracting Officer, each Project Team must spend at least 5% of the Federal funding (i.e., the portion of the award that does not include the recipient's cost share) on Technology Transfer & Outreach (TT&O) activities to promote and further the development and deployment of ARPA-E-funded technologies. In addition, Project Teams may not expend more than 5% of the Total Project Cost on TT&O activities without the prior approval of the Contracting Officer (see Section IV.G.8 of the FOA).
- All TT&O costs requested must be included in the Applicant's proposed budget and identified as TT&O costs in the Budget Justification Workbook/SF-424A with the costs being requested under the "Other" budget category. All budgeted activities must relate to achieving specific objectives, technical milestones and deliverables outlined in the Technical Milestones and Deliverables.
- For pricing purposes, assume a project start date of 11/01/2013, or as negotiated.
- For more information, please refer to the ARPA-E Budget Justification Guidance document at <https://arpa-e-foa.energy.gov>.

#### **4. FOURTH COMPONENT: TECHNICAL MILESTONES AND DELIVERABLES**

Applicants must submit proposed Technical Milestones and Deliverables in one combined PDF document. The Technical Milestones and Deliverables include (1) a statement of project objectives, (2) a schedule for the work proposed in the "R&D Tasks" section of the Technical Volume, and (3) a set of detailed descriptions of the technical Tasks, Sub-Tasks, Milestones, and Deliverables. Please refer to the "Technical Milestones and Deliverables – Instructions and Examples" document available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>) for guidance on preparing the Technical Milestones and Deliverables.

The Technical Milestones and Deliverables help focus effort and resources on critical path technology components. The technical Tasks, Sub-Tasks, Milestones, and Deliverables should provide a clear path to completion of the R&D Tasks and be as quantitative and specific as possible, clearly indicating the techniques and assumptions used to determine their achievement. ARPA-E evaluates the progress of a project by comparing actual progress of completing Tasks and Sub-Tasks to predetermined technical milestones and deliverables.

End-of-Project or other milestones may be subject to independent measurement or verification. ARPA-E Program Directors may require revisions to proposed Technical Milestones and Deliverables during award negotiations. In addition, ARPA-E Program Directors may redirect, discontinue, or terminate projects that fail to achieve predetermined Technical Milestones and Deliverables.

## **5. FIFTH COMPONENT: SUMMARY FOR PUBLIC RELEASE**

Applicants are required to provide a one-page Summary for Public Release. A Summary for Public Release template is available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>). The Summary for Public Release must be submitted in Adobe PDF format. This summary should not include any confidential, proprietary, or privileged information. The summary should be written for a lay audience (e.g., general public, media, Congress) using plain English.

## **6. SIXTH COMPONENT: SUMMARY SLIDE**

Applicants are required to provide a single PowerPoint slide summarizing the proposed project. The slide must be submitted in Microsoft PowerPoint format. This slide is used during the evaluation process. A summary slide template is available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>). A sample summary slide is also available on ARPA-E eXCHANGE. Applicants must use the Summary Slide template to complete their Summary Slide.

The Summary Slide template requires the following information:

- a technology summary;
- a description of the technology's impact;
- proposed targets;
- any key graphics (illustrations, charts and/or tables);
- the project's key idea/takeaway;
- project title and Principal Investigator information; and
- requested ARPA-E funds and proposed applicant cost share.

## **7. SEVENTH COMPONENT: BUSINESS ASSURANCES FORM**

Applicants are required to complete a Business Assurances Form. The form must be submitted in Adobe PDF format. This form is available on ARPA-E eXCHANGE at <https://arpa-e-foa.energy.gov>. A sample response to the Business Assurances Form is also available on ARPA-E eXCHANGE.

In the Business Assurances Form, the Applicant is required to:

- Disclose potential improprieties, such as convictions for fraud and export control violations;
- Disclose potential conflicts of interest within the Project Team; and

- Provide written assurance of its cost share commitment;
- If the Applicant is a FFRDC, submit written authorization from the cognizant Federal agency; and
- If the Applicant is a DOE/NNSA FFRDC, submit a Field Work Proposal.

In addition, the Applicant may:

- Request authorization to perform some work overseas;
- Request a waiver of the TT&O spending requirement;
- Request the use of a Technology Investment Agreement instead of ARPA-E's Model Cooperative Agreement; and
- Request a modification or waiver of the U.S. Manufacturing requirement.

## **8. EIGHTH COMPONENT: OTHER SOURCES OF FUNDING DISCLOSURE FORM**

ARPA-E is required by statute to “accelerat[e] transformational technological advances in areas that industry is by itself not likely to undertake because of technical and financial uncertainty.”<sup>43</sup> In accordance with its statutory mandate, ARPA-E requires the PI to complete the Other Sources of Funding Disclosure Form and submit it with the Full Application. The form must be submitted in Adobe PDF format. The Other Sources of Funding Disclosure Form is available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>). A sample response to the Other Sources of Funding Disclosure Form is also available on ARPA-E eXCHANGE.

In the Other Sources of Funding Disclosure Form, the PI is required to:

- Describe the additionality and risks associated with the proposed R&D project;
- Disclose whether the PI or any Co-PI(s) have submitted the same application to any Federal or non-Federal entities;
- Disclose whether the PI or any Co-PI(s) have submitted any applications for related work to any Federal or non-Federal entities within the last 24 months;

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<sup>43</sup> America COMPETES Act, Pub. L. No. 110-69, § 5012 (2007), as amended (codified at 42 U.S.C. § 16538).

- Disclose all financial assistance from any Federal entity that the PI or any Co-PI(s) is currently receiving or has received within the last 5 years;
- Disclose any funding from non-Federal entities for related work that the PI or any Co-PI(s) is currently receiving or has received within the last 5 years; and
- Provide any letters or other communications from private investors explaining why they decided not to fund the proposed R&D project or related work.

## **9. NINTH COMPONENT: REMOTE CALCULATOR TOOL**

Full Application Category 3 Applicants are required to submit a completed REMOTE Calculator Tool. Category 3 Applicants may access the REMOTE Calculator Tool template in ARPA-E eXCHANGE(<https://arpa-e-foa.energy.gov>).

The purpose of the REMOTE Calculator Tool template is to provide Category 3 Applicants with a normalized framework for ascribing cost to technology capital and operations in order to address primary technical target 3.1 ("Overall Process CapEx"). Category 3 Applicants' responses in the REMOTE Calculator Tool will be evaluated and reviewed by ARPA-E as part of the Category 3 Applicants' Full Application.

The REMOTE Calculator Tool template is comprised of 10 tabs: "start"; "proposed"; "parameters"; "capex"; "opex"; "summary"; "bioconversion"; "detailed"; "suffix"; and "case1." The "start" tab contains written guidance for completing the spreadsheets. The REMOTE Calculator Tool template contains an example reference case termed "Case 1" that specifically pertains to an aerobic process for bio-conversion of methane to fatty acids and includes unit operations for fatty acid separation and hydrotreatment. The reference "Case 1" contains example equipment and operations costs, and example calculations. "Case 1" is intended to (1) provide an example of the functionality of the REMOTE Calculator Tool template and (2) provide an informational base-case which Category 3 Applicants can either accept and use or bypass and/or replace with data specific to their proposed technology.

ARPA-E will post a link to a brief instructional webinar on how to navigate and best use the REMOTE Calculator Tool template on ARPA-E eXCHANGE(<https://arpa-e-foa.energy.gov>). Technical questions about the REMOTE Calculator Tool template must be addressed to [ARPA-E-CO@hq.doe.gov](mailto:ARPA-E-CO@hq.doe.gov).

ARPA-E funds high-risk technology development and is cognizant of the fact that many early-stage technologies may not have sufficient empirical data to support highly accurate values for

technology performance and cost. In such cases, Category 3 Applicants are encouraged to clearly notate the source and/or relevant assumptions.

Category 3 Applicants are required to submit a detailed cost and performance analysis using the REMOTE Calculator Tool template (or equivalent tool of comparable detail) tailored to the proposed technology. If submitting an equivalent tool, Category 3 Applicants must provide, at a minimum, the information identified on the “summary” tab of the REMOTE Calculator Tool template.

Category 3 Applicants must upload their completed REMOTE Calculator Tool template or equivalent tool into ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>).

#### **E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS**

~~[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]~~

Written feedback on Full Applications is made available to Applicants before the submission deadline for Replies to Reviewer Comments. Applicants have a brief opportunity to prepare a short Reply to Reviewer Comments responding to one or more comments or supplementing their Full Application. A fillable Reply to Reviewer Comments template is available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>). Applicants must use this Reply to Reviewer Comments template to complete their Reply to Reviewer Comments.

Replies to Reviewer Comments must conform to the following requirements:

- The Reply to Reviewer Comments must be submitted in Adobe PDF format.
- The Reply to Reviewer Comments 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. Use Times New Roman typeface, a black font color, and a font size of 12 points or larger (except in figures and tables).
- The Control Number 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.

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments (see Section III.C.1 of the FOA). 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.

Replies to Reviewer Comments must conform to the following content and form requirements, including maximum page lengths, described below. If a Reply to Reviewer Comments is more



than three pages in length, ARPA-E will review only the first three pages and disregard any additional pages.

SECTION	PAGE LIMIT	DESCRIPTION
Text	2 pages maximum	<ul style="list-style-type: none"><li>Applicants may respond to one or more reviewer comments or supplement their Full Application.</li></ul>
Images	1 page maximum	<ul style="list-style-type: none"><li>Applicants may provide graphs, charts, or other data to respond to reviewer comments or supplement their Full Application.</li></ul>

#### **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 MAY 2013]~~

##### **1. ALLOWABLE COSTS**

All expenditures must be allowable, allocable, and reasonable in accordance with the applicable Federal cost principles. ARPA-E has listed the Federal cost principles for different categories of Applicants at [http://arpa-e.energy.gov/FundingAgreements/Overview/PostAward.aspx#Applicable\\_Federal\\_Regulations](http://arpa-e.energy.gov/FundingAgreements/Overview/PostAward.aspx#Applicable_Federal_Regulations).

##### **2. PRE-AWARD COSTS**

ARPA-E will not reimburse any pre-award costs incurred by Applicants before they are selected for award negotiations. Please refer to Section VI.A of the FOA for guidance on award notices.

Upon selection for award negotiations, Applicants may incur pre-award costs at their own risk, consistent with the requirements in 10 C.F.R. part 600 and other Federal laws and regulations. ARPA-E generally does not accept budgets as submitted with the Full Application. Budgets are typically reworked during award negotiations. ARPA-E is under no obligation to reimburse pre-award costs if, for any reason, the Applicant does not receive an award or the award is made for a lesser amount than the Applicant expected, or if the costs incurred are not allowable, allocable, or reasonable.

Given the uncertainty of award negotiations, it is strongly recommended that Prime Recipients and Subrecipients consult with the Contracting Officer ([ARPA-E-CO@hq.doe.gov](mailto:ARPA-E-CO@hq.doe.gov)) before incurring any pre-award costs.

Please refer to the “Applicants’ Guide to ARPA-E Award Negotiations” (<http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf>) for additional guidance on pre-award costs.

### **3. PATENT COSTS**

ARPA-E will fully reimburse the following types of patent costs:

- Cost of preparing and submitting invention disclosures to ARPA-E and DOE;
- Cost of searching the art to the extent reasonable and necessary to make invention disclosures to ARPA-E and DOE, as required by Attachment 2 to the funding agreement; and
- Cost of preparing the reports and other documents required by Attachment 2 to the funding agreement.

ARPA-E will reimburse up to \$30,000 in costs and fees incurred in preparing and filing domestic and foreign patents. The Prime Recipient may request a waiver of the \$30,000 cap. Because all patent costs are considered to be Technology Transfer & Outreach (TT&O) costs (see Section IV.G.8 of the FOA below), the waiver request is subject to review by the ARPA-E Program Director and approval by the Contracting Officer.

### **4. CONSTRUCTION**

ARPA-E generally does not fund projects that involve major construction. Recipients are required to obtain written authorization from the Contracting Officer before incurring any major construction costs.

### **5. FOREIGN TRAVEL**

ARPA-E generally does not fund projects that involve foreign travel. Recipients are required to obtain written authorization from the Contracting Officer before incurring any foreign travel costs and provide trip reports with their reimbursement requests.

### **6. PERFORMANCE OF WORK IN THE UNITED STATES**

ARPA-E strongly encourages interdisciplinary and cross-sectoral collaboration spanning organizational boundaries. Such collaboration enables the achievement of scientific and technological outcomes that were previously viewed as extremely difficult, if not impossible.

ARPA-E requires all work under ARPA-E funding agreements to be performed in the United States – i.e., Prime Recipients must expend 100% of the Total Project Cost in the United States. However, Applicants may request a waiver of this requirement where their project would materially benefit from, or otherwise requires, certain work to be performed overseas.

Applicants seeking a waiver of this requirement are required to include an explicit request in the Business Assurances Form, which is part of the Full Application submitted to ARPA-E. Such waivers are granted where there is a demonstrated need, as determined by ARPA-E.

## **7. PURCHASE OF NEW EQUIPMENT**

All new equipment purchased under ARPA-E funding agreements must be made or manufactured in the United States, to the maximum extent practicable. This requirement does not apply to used or leased equipment. Project Teams may purchase foreign-made equipment where comparable domestic equipment is not reasonably available.

## **8. TECHNOLOGY TRANSFER AND OUTREACH**

By law, ARPA-E is required to contribute a percentage of appropriated funds to Technology Transfer and Outreach (TT&O) activities. In order to meet this mandate every Project Team must spend at least 5% of the Federal funding (i.e., the portion of the award that does not include the recipient's cost share) provided by ARPA-E on TT&O activities to promote and further the development and deployment of ARPA-E-funded technologies. Project Teams may not expend more than 5% of the Total Project Cost on TT&O activities without the prior approval of the Contracting Officer. Project Teams must also seek a waiver from the Contracting Officer to spend less than the minimum 5% TT&O expenditure requirement.

All TT&O expenditures are subject to the applicable Federal cost principles, as described in Section IV.G.1 of the FOA. Examples of TT&O expenditures are as follows:

- Documented travel and registration for the ARPA-E Energy Innovation Summit and other energy-related conferences and events;
- Documented travel to meet with potential suppliers, partners, or customers;
- Documented work by salaried or contract personnel to develop technology-to-market models or plans;
- Documented costs of acquiring industry-accepted market research reports; and

- Approved patent costs.

ARPA-E will not reimburse the following types of TT&O expenditures, which do not comply with Federal cost principles.

- Meals or entertainment;
- Gifts to potential suppliers, partners, or customers;
- TT&O activities that do not relate to the ARPA-E-funded technologies or to at least one objective in the Technical Milestones and Deliverables;
- Undocumented TT&O activities; and
- TT&O activities unrelated and/or unallocable to the subject award.

Applicants may seek a waiver of the TT&O requirement by including an explicit request in the Business Assurances Form. Please refer to the Business Assurances Form for guidance on the content and form of the waiver request. ARPA-E Program Directors may waive or modify the TT&O requirement, as appropriate.

For information regarding incorporation of TT&O costs into budget documentation, see Section IV.D.3 of the FOA.

Please refer to the “Applicants’ Guide to ARPA-E Award Negotiations” (<http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf>) for additional guidance on TT&O requirements.

## **9. LOBBYING**

Prime Recipients and Subrecipients may not use any Federal funds to influence or attempt to influence, directly or indirectly, congressional action on any legislative or appropriation matters.<sup>44</sup>

Prime Recipients and Subrecipients are required to complete and submit SF-LLL, “Disclosure of Lobbying Activities” (<http://www.whitehouse.gov/sites/default/files/omb/grants/sflllin.pdf>) if any non-Federal funds have been paid or will be paid to any person for influencing or attempting to influence any of the following in connection with your application:

- An officer or employee of any Federal agency,

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<sup>44</sup> 18 U.S.C. § 1913.

- A Member of Congress,
- An officer or employee of Congress, or
- An employee of a Member of Congress.

## 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 User 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 will not review or consider incomplete applications and applications submitted after the deadline stated in the FOA.** Such applications will 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;
- 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 State of the Art* (50%) - This criterion involves consideration of the following factors:

- The extent to which the proposed quantitative material and/or technology metrics demonstrate the potential for a transformational and disruptive (not incremental) advancement in one or more energy-related fields;
- The extent to which the Applicant demonstrates a profound understanding of the current state-of-the-art and presents an innovative technical approach that significantly improves performance relative to the current state-of-the-art; and
- The extent to which the Applicant demonstrates 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 factors:

- The extent to which the proposed approach is unique and innovative;
- The feasibility of the proposed work;
- The extent to which the Applicant proposes a sound technical approach to accomplish the proposed R&D objectives;
- The extent to which project outcomes and deliverables are clearly defined; and

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

- The extent to which the Applicant proposes a strong and convincing technology development strategy, including a feasible pathway to transition the program results to the next logical stage of R&D and/or directly into commercial development and deployment.

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 State of the Art	50%
Overall Scientific and Technical Merit	50%

## 2. CRITERIA FOR FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]

Full Applications are evaluated based on the following criteria:

(1) *Impact of the Proposed Technology Relative to State of the Art* (30%) - This criterion involves consideration of the following factors:

- The extent to which the proposed quantitative material and/or technology metrics demonstrate the potential for a transformational and disruptive (not incremental) advancement in one or more energy-related fields;
- The extent to which the Applicant demonstrates a profound understanding of the current state-of-the-art and presents an innovative technical approach to significantly improve performance over the current state-of-the-art; and
- The extent to which the Applicant demonstrates awareness of competing commercial and emerging technologies and identifies how its proposed concept/technology provides significant improvement over these other solutions.

(2) *Overall Scientific and Technical Merit* (30%) - This criterion involves consideration of the following factors:

- The extent to which the proposed work is unique and innovative;
- The extent to which the proposed project is likely to meet or exceed the technical performance targets identified in this FOA;



- The feasibility of the proposed work;
- The extent to which the Applicant proposes a sound technical approach to accomplish the proposed R&D objectives;
- The extent to which the Applicant manages risk, by identifying major technical R&D risks and clearly proposes feasible, effective mitigation strategies; and
- The extent to which project outcomes and deliverables are clearly defined; and
- The extent to which the Applicant proposes a strong and convincing technology development strategy, including a feasible pathway to transition the program results to the next logical stage of R&D and/or directly into commercial development and deployment.

(3) *Qualifications, Experience, and Capabilities of the Proposed Project Team* (30%) - This criterion involves consideration of the following factors:

- The extent to which the PI and Project Team have the skill and expertise needed to successfully execute the project plan, evidenced by prior experience that demonstrates an ability to perform R&D of similar risk and complexity;
- The extent to which the Applicant has access to the equipment and facilities necessary to accomplish the proposed R&D effort and/or a clear plan to obtain access to necessary equipment and facilities.

(4) *Soundness of Management Plan* (10%) - This criterion involves consideration of the following factors:

- The extent to which the Applicant presents a plausible plan to manage people and resources;
- The extent to which the Applicant proposes allocation of appropriate levels of effort and resources to proposed tasks;
- Whether the proposed schedule is reasonable.

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 State of the Art	30%
Overall Scientific and Technical Merit	30%
Qualifications, Experience, and Capabilities	30%
Sound Management Plan	10%

### 3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

~~[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]~~

ARPA-E has not established separate criteria to evaluate Replies to Reviewer Comments. Instead, Replies to Reviewer Comments are evaluated as an extension of the Full Application.

#### B. REVIEW AND SELECTION PROCESS

##### 1. PROGRAM POLICY FACTORS

~~[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]~~

In addition to the above criteria, ARPA-E may consider the following program policy factors in determining 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. Technological diversity;
- b. Organizational diversity;
- c. Geographic diversity;
- d. Technical or commercialization risk; or
- e. 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 US dependence on foreign energy sources;
- b. Stimulation of domestic manufacturing;
- 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 DOE Contracting Officer by email ([ARPA-E-CO@hq.doe.gov](mailto:ARPA-E-CO@hq.doe.gov)) if they have knowledge of a potential conflict of interest or a reasonable belief that a potential conflict exists.

## **3. ARPA-E SUPPORT CONTRACTOR**

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

By submitting an application to ARPA-E, Applicants represent that they are not performing support contractor services for ARPA-E in any capacity and did not obtain the assistance of ARPA-E's support 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 MAY 2013]~~

ARPA-E expects to announce selections for negotiations in approximately August 2013 and to execute funding agreements in approximately November 2013.

## **VI. AWARD ADMINISTRATION INFORMATION**

### **A. AWARD NOTICES**

#### **1. REJECTED SUBMISSIONS**

Noncompliant and nonresponsive Concept Papers and Full Applications are rejected by the DOE Contracting Officer and are not reviewed or considered. The DOE 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. Due to the anticipated volume of applications, ARPA-E is unable to provide feedback on Concept Papers.

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 or the Applicant. 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.2 of the FOA for guidance on pre-award costs.

#### **3. FULL APPLICATION NOTIFICATIONS**

**[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]**

ARPA-E promptly notifies Applicants of its determination. ARPA-E 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 may inform the Applicant that its Full Application was selected for award negotiations, or not selected. Alternatively, ARPA-E may notify one or more Applicants that a final selection determination on particular Full Applications will be made

at a later date, subject to the availability of funds or other factors.

Written feedback on Full Applications is made available to Applicants before the submission deadline for Replies to Reviewer Comments. By providing feedback, ARPA-E intends to guide the further development of the proposed technology and to provide a brief opportunity to respond to reviewer comments.

#### ***a. SUCCESSFUL APPLICANTS***

ARPA-E has discretion to select all or part of a proposed project for negotiation of an award. A notification letter selecting a Full Application for award negotiations does not authorize the Applicant to commence performance of the project. **ARPA-E selects Full Applications for award negotiations, not for award.** Applicants do not receive an award until award negotiations are complete and the Contracting Officer executes the funding agreement. ARPA-E may terminate award negotiations at any time for any reason.

Please refer to Section IV.G.2 of the FOA for guidance on pre-award costs. Please also refer to the “Applicants’ Guide to ARPA-E Award Negotiations” (<http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf>) for guidance on the award negotiation process.

#### ***b. POSTPONED SELECTION DETERMINATIONS***

A notification letter postponing a final selection determination until a later date does not authorize the Applicant to commence performance of the project. ARPA-E may ultimately determine to select or not select the Full Application for award negotiations.

Please refer to Section IV.G.2 of the FOA for guidance on pre-award costs.

#### ***c. UNSUCCESSFUL APPLICANTS***

By not selecting 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. ARPA-E hopes that unsuccessful Applicants will submit innovative ideas and concepts for future FOAs.

## **B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS**

~~[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]~~

The following administrative and national policy requirements apply to Prime Recipients. The Prime Recipient is the responsible authority regarding the settlement and satisfaction of all contractual and administrative issues, including but not limited to disputes and claims arising out of any agreement between the Prime Recipient and a FFRDC contractor. Prime Recipients are required to flow down these requirements to their Subrecipients through subawards or related agreements.

### **1. DUNS NUMBER AND SAM, FSRS, AND FEDCONNECT REGISTRATIONS**

Upon selection for award negotiations, Prime Recipients and Subrecipients are required to obtain a Dun and Bradstreet Data Universal Numbering System (DUNS) number at <http://fedgov.dnb.com/webform>. In addition, Prime Recipients and Subrecipients are required to register with the System for Award Management (SAM) at <https://www.sam.gov/portal/public/SAM/>. Applicants who currently have an active record in the Central Contractor Registry (CCR) have an active record in SAM, but a new username must still be registered.

Prime Recipients and Subrecipients should commence this process as soon as possible in order to expedite the execution of a funding agreement. Obtaining a DUNS number and registering with SAM could take several weeks.

By law, Prime Recipients are also required to register with the Federal Funding Accountability and Transparency Act Subaward Reporting System (FSRS) at <https://www.fsrs.gov/>.<sup>45</sup> Prime Recipients are required to report to FSRS the names and total compensation of each of the Prime Recipient's five most highly compensated executives and the names and total compensation of each Subrecipient's five most highly compensated executives. Please refer to <https://www.fsrs.gov/> for guidance on reporting requirements.

ARPA-E may not execute a funding agreement with the Prime Recipient until it has obtained a DUNS number and completed its SAM and FSRS registrations. In addition, the Prime Recipient may not execute subawards with Subrecipients until they obtain a DUNS number and complete their SAM registration. Prime Recipients and Subrecipients are required to keep their SAM and FSRS data current throughout the duration of the project.

Finally, Prime Recipients are required to register with FedConnect in order to receive notification that their funding agreement has been executed by the Contracting Officer and to

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<sup>18</sup> The Federal Funding Accountability and Transparency Act, P.L. 109-282, 31 U.S.C. 6101 note.

obtain a copy of the executed funding agreement. Please refer to <https://www.fedconnect.net/FedConnect/> for registration instructions.

## **2. NATIONAL POLICY ASSURANCES**

Project Teams, including Prime Recipients and Subrecipients, are required to comply with the National Policy Assurances attached to their funding agreement. Please refer to ARPA-E's Model Cooperative Agreement (<http://arpa-e.energy.gov/FundingAgreements/CooperativeAgreements.aspx>) for guidance on the National Policy Assurances.

## **3. PROOF OF COST SHARE COMMITMENT AND ALLOWABILITY**

Upon selection for award negotiations, the Prime Recipient must confirm in writing that the proposed cost share contribution is allowable in accordance with applicable Federal cost principles.

The Prime Recipient is also required to provide cost share commitment letters from Subrecipients or third parties that are providing cost share, whether cash or in-kind. Each Subrecipient or third party that is contributing cost share must provide a letter on appropriate letterhead that is signed by an authorized corporate representative. Please refer to the "Applicants' Guide to ARPA-E Award Negotiations" (<http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf>) for guidance on the contents of cost share commitment letters.

## **4. COST SHARE PAYMENTS<sup>46</sup>**

All proposed cost share contributions must be reviewed in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

ARPA-E requires Prime Recipients to contribute the cost share amount incrementally over the life of the funding agreement.<sup>47</sup> Specifically, every Prime Recipient is required to contribute, at a minimum, the cost share percentage of total expenditures incurred during every billing period. For example, a Prime Recipient is required to contribute at least 31% of the total expenditures incurred during every billing period if the funding agreement states that the cost share percentage is 31%.

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<sup>19</sup> Please refer to Section III.B of the FOA for guidance on cost share requirements.

<sup>20</sup> Prime Recipients may elect to pay the entire cost share amount at the start of the project.



Prime Recipients must submit written documentation with every reimbursement request demonstrating that it (or Project Team, as appropriate) has provided the requisite cost share during the relevant billing period.

If Prime Recipients anticipate difficulty providing the requisite cost share every billing period, they may request authorization from the Contracting Officer upon selection for award negotiations to deviate from ARPA-E's standard cost share payment schedule.

Please refer to the "Applicants' Guide to ARPA-E Award Negotiations" (<http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf>) for additional guidance on cost share payment requirements.

ARPA-E may deny reimbursement requests, in whole or in part, or modify or terminate funding agreements where Prime Recipients (or Project Teams) fail to comply with ARPA-E's cost share payment requirements.

## **5. ENVIRONMENTAL IMPACT QUESTIONNAIRE**

By law, ARPA-E is required to evaluate the potential environmental impact of projects that it is considering for funding. In particular, ARPA-E must determine before funding a project whether the project qualifies for a categorical exclusion under 10 C.F.R. § 1021.410 or whether it requires further environmental review (i.e., an environmental assessment or an environmental impact statement).

To facilitate and expedite ARPA-E's environmental review, Prime Recipients are required to complete an Environmental Impact Questionnaire during award negotiations. This form is available on ARPA-E eXCHANGE at <https://arpa-e-foa.energy.gov>. The Environmental Impact Questionnaire is due within 21 calendar days of the selection announcement.

## **6. TECHNOLOGY-TO-MARKET PLAN**

During award negotiations, Prime Recipients are required to negotiate and submit an initial Technology-to-Market Plan to the ARPA-E Program Director, and obtain the ARPA-E Program Director's approval prior to the execution of the award. Prime Recipients must show how budgeted Technology Transfer and Outreach (TT&O) costs relate to furthering elements of the Technology-to-Market Plan. During the project period, Prime Recipients are required to provide regular updates on the initial Technology-to-Market plan and report on implementation of Technology-to-Market activities. Prime Recipients may be required to perform other actions to further the commercialization of their respective technologies.

ARPA-E Program Directors may waive or modify this requirement, as appropriate.

## **7. INTELLECTUAL PROPERTY MANAGEMENT PLAN**

ARPA-E requires every Project Team to negotiate and establish an Intellectual Property Management Plan for the management and disposition of intellectual property arising from the project. The Prime Recipient must submit a completed and signed Intellectual Property Management plan to ARPA-E within six weeks of the effective date of the ARPA-E funding agreement. All Intellectual Property Management Plans are subject to the terms and conditions of the ARPA-E funding agreement and its intellectual property provisions, and applicable Federal laws, regulations, and policies, all of which take precedence over the terms of Intellectual Property Management Plans.

ARPA-E has developed a template for Intellectual Property Management Plans (<http://arpa-e.energy.gov/FundingAgreements/Overview.aspx>) so as to facilitate and expedite negotiations between Project Team members. ARPA-E does not mandate the use of this template. ARPA-E and DOE do not make any warranty (express or implied) or assume any liability or responsibility for the accuracy, completeness, or usefulness of the template. ARPA-E and DOE strongly encourage Project Teams to consult independent legal counsel before using the template.

## **8. U.S. MANUFACTURING REQUIREMENT**

ARPA-E requires products embodying or produced through the use of subject inventions (i.e., inventions conceived or first actually reduced to practice under ARPA-E funding agreements) to be substantially manufactured in the United States by Project Teams and their licensees, as described below. The Applicant may request a modification or waiver of the U.S. Manufacturing Requirement through the Business Assurances Form submitted with the Full Application.

### ***a. SMALL BUSINESSES***

Small businesses (including Small Business Concerns) that are Prime Recipients or Subrecipients under ARPA-E funding agreements are required to substantially manufacture the following products in the United States for any use or sale in the United States: (1) products embodying subject inventions, and (2) products produced through the use of subject invention(s).<sup>48</sup> This requirement does not apply to products that are manufactured for use or sale outside the U.S.

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<sup>22</sup> Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" ([http://www.sba.gov/sites/default/files/Size\\_Standards\\_Table.pdf](http://www.sba.gov/sites/default/files/Size_Standards_Table.pdf)).

Small businesses must apply the same U.S. Manufacturing requirements to their assignees, licensees, and entities acquiring a controlling interest in the small business. Small businesses must require their assignees and entities acquiring a controlling interest in the small business to apply the same U.S. Manufacturing requirements to their licensees.

### ***b. LARGE BUSINESSES AND FOREIGN ENTITIES***

Large businesses and foreign entities that are Prime Recipients or Subrecipients under ARPA-E funding agreements are required to substantially manufacture the following products in the United States: (1) products embodying subject inventions, and (2) products produced through the use of subject invention(s).<sup>49</sup> This requirement applies to products that are manufactured for use or sale in the United States and outside the United States.

Large businesses and foreign entities must apply the same U.S. Manufacturing requirements to their assignees, licensees, and entities acquiring a controlling interest in the large business or foreign entity. Large businesses and foreign entities must require their assignees and entities acquiring a controlling interest in the large business or foreign entity to apply the same U.S. Manufacturing requirements to their licensees.

### ***c. EDUCATIONAL INSTITUTIONS AND NONPROFITS***

Domestic educational institutions and nonprofits that are Prime Recipients or Subrecipients under ARPA-E funding agreements must require their exclusive licensees to substantially manufacture the following products in the United States for any use or sale in the United States: (1) articles embodying subject inventions, and (2) articles produced through the use of subject invention(s). This requirement does not apply to articles that are manufactured for use or sale overseas.

Educational institutions and nonprofits must require their assignees to apply the same U.S. Manufacturing requirements to their exclusive licensees.

These U.S. Manufacturing requirements do not apply to nonexclusive licensees.

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<sup>49</sup> Large businesses are generally defined as domestically incorporated entities that do not meet the criteria established by the U.S. Small Business Administration's "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" ([http://www.sba.gov/sites/default/files/Size\\_Standards\\_Table.pdf](http://www.sba.gov/sites/default/files/Size_Standards_Table.pdf)).

**d. FFRDCs and State and Local Government Entities**

FFRDCs and state and local government entities are subject to the same U.S. Manufacturing requirements as domestic educational institutions and nonprofits.

**C. REPORTING**

~~[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]~~

Recipients are required to submit periodic, detailed reports on technical, financial, and other aspects of the project, as described in Attachment 4 to ARPA-E's Model Cooperative Agreement (<http://arpa-e.energy.gov/FundingAgreements/CooperativeAgreements.aspx>).

## **VII. AGENCY CONTACTS**

### **A. COMMUNICATIONS WITH ARPA-E**

Upon the issuance of a FOA, ARPA-E personnel are prohibited from communicating (in writing or otherwise) with Applicants regarding the FOA. This “quiet period” remains in effect until ARPA-E’s public announcement of its project selections.

During the “quiet period,” Applicants are required to submit all questions regarding this FOA to [ARPA-E-CO@hq.doe.gov](mailto:ARPA-E-CO@hq.doe.gov).

- ARPA-E will post responses on a weekly basis to any questions that are received. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.
- ARPA-E will cease to accept questions approximately 5 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 posted to “Frequently Asked Questions” on ARPA-E’s website (<http://arpa-e.energy.gov/faq>).

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

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

During the “quiet period,” only the DOE Contracting Officer may authorize communications between ARPA-E personnel and Applicants. The DOE Contracting Officer may communicate with Applicants as necessary and appropriate. As described in Section **1.B IV.A** of the FOA, the DOE 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. 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>.

### **B. OBLIGATION OF PUBLIC FUNDS**

The DOE 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 DOE 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.

### **C. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE**

Applicants are required to make a full and complete disclosure of the information requested in the Business Assurances Form and the Other Sources of Funding Disclosure 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.

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

#### **D. 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.

#### **E. 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. Applicants should not include confidential, proprietary, or privileged information in their Concept Papers, Full Applications, or Replies to Reviewer Comments unless such information is necessary to convey an understanding of the proposed project.

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.



## **F. 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 they elect to retain title, they must file a patent application in a timely fashion.**
- All other parties: The Federal Non Nuclear Energy 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 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.**

## **G. 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 ~~satisfied~~ **satisfactory** manner;
- The owner has not met public use requirements specified by Federal statutes in a reasonably ~~satisfied~~ **satisfactory** manner; or
- The U.S. Manufacturing requirement has not been met.

#### **H. RIGHTS IN TECHNICAL DATA**

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

- 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. Such data should be clearly marked as described in Section VIII.E of the FOA. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

#### **I. 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).

#### **J. ANNUAL COMPLIANCE AUDITS FOR FOR-PROFIT ENTITIES**

~~[TO BE INSERTED BY FOA MODIFICATION IN MAY 2013]~~

If a for-profit entity is a Prime Recipient or Subrecipient, an annual compliance audit performed by an independent auditor may be required. For additional information, please refer to 10 C.F.R. § 600.316 and for-profit audit guidance documents posted under the "Coverage of Independent Audits" heading at [http://management.energy.gov/business\\_doe/business\\_forms.htm](http://management.energy.gov/business_doe/business_forms.htm).

## **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:** Advanced Research Projects Agency-Energy.

**Cost Share:** The Prime Recipient share of the Total Project Cost.

**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

**Down-Select Process:** Once ARPA-E completes its review of Full Applications and Replies to Reviewer Comments, it will perform a “down-select” of Full Applications. Certain Applicants will be invited to participate in a meeting with ARPA-E via webinar, videoconference, or conference call. In the alternative, ARPA-E may invite Applicants to meet in person at ARPA-E’s offices, the recipient’s site, or a mutually agreed upon location. ARPA-E may also conduct pre-selection site visits to certain Applicants’ facilities.

**FFRDCs:** Federally Funded Research and Development Centers.

**FOA:** Funding Opportunity Announcement.

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

**Key Participant:** Any individual who would contribute in a substantive, measurable way to the execution of the proposed project.

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

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

**PI:** Principal Investigator.

**Processing Energy:** The total amount of energy required to extract primary metal from ore.

**Project Team:** A Project Team consists of the Prime Recipient, Subrecipients, and others performing or otherwise supporting work under an ARPA-E funding agreement.

**R&D:** Research and development.

**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 FFRDCs and GOGOs.

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