

**FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT**



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

**GENerators for Small Electrical and Thermal Systems
(GENSETS)**

Announcement Type: **Initial Announcement Modification 01**
Funding Opportunity No. DE-FOA-0001198
CFDA Number 81.135

FOA Issue Date:	October 16, 2014
First Deadline for Questions to ARPA-E-CO@hq.doe.gov :	5 PM ET, November 24, 2014
Submission Deadline for Concept Papers:	5 PM ET, December 01, 2014
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov :	5 PM ET, TBD March 16, 2015
Submission Deadline for Full Applications:	5 PM ET, TBD March 23, 2015
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD May 6, 2015
Expected Date for Selection Notifications:	TBD May, 2015
Total Amount to Be Awarded	Approximately \$25 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between \$250,000 and \$10 million.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov/Registration.aspx>). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.H.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.
- 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 (with FOA name and number in subject line); see FOA Sec. VII.A.
Problems with ARPA-E eXCHANGE? Email ExchangeHelp@hq.doe.gov (with FOA name and number in subject line).

MODIFICATIONS

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

Mod. No.	Date	Description of Modifications
01	2/09/2015	<ul style="list-style-type: none">• Inserted certain deadlines, including the deadlines for submitting questions and Full Applications. See Cover Page and Required Documents Checklist.• Clarified supplementary explanation of targets, see Section I.E. of the FOA.• Provided C.F.R. citation, see Section II.B.3 of the FOA.• Clarified Cost Sharing, see Section III.B of the FOA.• 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 strongly encouraged to use the templates provided on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).• Inserted criteria that ARPA-E will use to evaluate Full Applications. See Section V.A.2 of the FOA.• Inserted criteria that ARPA-E will use to evaluate Replies to Reviewer Comments in Section V.A.3 of the FOA.• Inserted Program Policy Factors. See Section V.B.1 of the FOA.• Inserted information concerning Full Application Notifications. See Section VI.A.3 of the FOA.• Inserted Administrative and National Policy Requirements. See Section VI.B of the FOA.• Inserted Reporting Requirements. See Section VI.C of the FOA.• Inserted information concerning Class Waivers. See section VIII.F of the FOA.• Inserted regulations applicable to resulting awards. See Section VIII.I of the FOA.

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

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REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	<ul style="list-style-type: none"> Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: <ul style="list-style-type: none"> Concept Summary/Overview Proposed Work Team Organization and Capabilities 	Mandatory	IV.C	5 PM ET, December 01, 2014
Full Application	<p>[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]</p> <ul style="list-style-type: none"> Each Applicant must submit a Technical Volume in Adobe PDF format by the stated deadline. Applicants may use the Technical Volume template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov). The Technical Volume must include the following: <ul style="list-style-type: none"> Executive Summary (1 page max.) Sections 1-5 (30 pages max.) <ul style="list-style-type: none"> 1. Innovation 2. Proposed Work 3. Team Organization and Capabilities 4. Technology to Market 5. Budget Bibliographic References (no page limit) Personal Qualification Summaries (each PQS limited to 3 pages in length, no cumulative page limit) The Technical Volume must be accompanied by: <ul style="list-style-type: none"> SF-424 (no page limit, Adobe PDF format); Budget Justification Workbook/SF424A (no page limit, Microsoft Excel format) Summary for Public Release (250 words max., Adobe PDF format); Summary Slide (1 page limit, Microsoft PowerPoint format) – Applicants may use the Summary Slide template available on ARPA-E 	Mandatory	IV.D	5 PM ET, TBD March 23, 2015

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

	<p>eXCHANGE (https://arpa-e-foa.energy.gov); and</p> <ul style="list-style-type: none">○ Completed and signed Business Assurances & Disclosures Form (no page limit, Adobe PDF format).			
Reply to Reviewer Comments	<p>[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]</p> <ul style="list-style-type: none">• Each Applicant may submit a Reply to Reviewer Comments in Adobe PDF format. This submission is optional. Applicants may use the Reply to Reviewer Comments template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov). The Reply may include:<ul style="list-style-type: none">○ Up to 2 pages of text; and○ Up to 1 page of images.	Optional	IV.E	5 PM ET, TBD May 6, 2015

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.

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.
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.

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

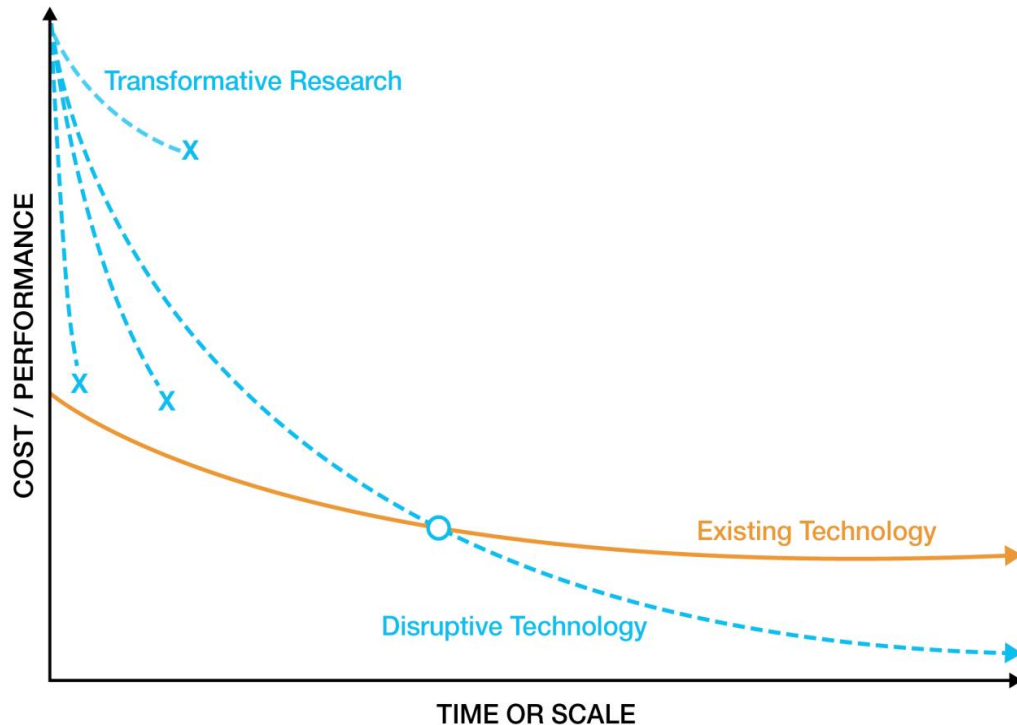


Figure 1: Description of transformational and disruptive technologies in terms of cost per unit performance versus time or scale. ARPA-E seeks to support research that establishes new learning curves that lead to disruptive technologies.

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 the economies of scale that accrue as manufacturing and widespread distribution develop drive technology down that learning curve until an equilibrium cost/performance is reached. 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 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

1. SUMMARY

The GENSETS Program – **GENerators for Small Electrical and Thermal Systems** – seeks to fund the development of potentially disruptive generator technologies that will enable widespread deployment of residential Combined Heat and Power (CHP) systems. Here, CHP is defined as the distributed generation of electricity from piped-in natural gas fuel at a residence or a commercial site complemented by use of exhaust heat for local heating and cooling. If adopted widely by U.S. residential and commercial sectors, GENSETS CHP systems could lead to annual primary energy *savings* of more than 5 quadrillion BTU (quads). GENSETS systems could also provide annual CO₂ emissions *reductions* of more than 200 million metric tons, which is roughly 10% of the CO₂ produced annually from U.S. electricity generation and 4% of total U.S. annual CO₂ emissions.

The GENSETS Program seeks transformative generators/engines with 1 kW of electrical output (kW_e) that have high efficiency (40% fuel to electricity), long life (10 years), low cost (\$3,000 per system), and low emissions. Heat engines and generators capable of achieving these targets may include internal and external combustion engines, turbines, and solid state devices such as thermophotovoltaics, thermionic emitters, and thermoelectrics. It is anticipated that the same technologies developed for 1-kW_e engines in GENSETS could be adapted to build larger engines with even higher efficiencies for various commercial sectors of the U.S.

2. BACKGROUND AND MOTIVATION

2.1 *Opportunity and Impact of CHP*

In 2013, U.S. central-station power plants consumed 38.2 quads of primary energy to generate 12.4 quads of electricity with an average electricity generation efficiency of 33% when aggregated over all primary energy sources, including coal, natural gas, nuclear, hydro, and wind¹. In the process, 67% of the primary energy was wasted as heat (25.8 quads) and about 2 billion metric tons of CO₂ were emitted to the environment, which is about 38% of the total annual U.S. CO₂ emissions². Distributed CHP systems are an alternative to central-station power plants. In these systems, an electrical generation system located in a residence or at a commercial site consumes natural gas to generate electricity locally and then the exhaust heat is utilized for local heating needs (in contrast to being wasted at central-stations). The combined efficiency of primary energy usage in CHP can be higher than 80%. Since about 75% of the electricity generated from all central-station power plants is consumed by the residential and commercial sectors, CHP in these sectors can have a huge impact on both energy savings and CO₂ emissions reduction. In addition, CHP can bring power resilience to households and

¹ https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2013/2013USEnergy.png

² www.eia.gov

commercial entities to counter weather-related outages that cause billions of dollars of losses to the U.S. economy annually.³

The current best-performing engines for CHP at small-scale (<2-kW_e) have a fuel-to-electricity efficiency of about 26% and a Capital Expenditure (CAPEX) of more than \$6,000 per kW_e. The combination of low efficiency and high cost has significantly limited CHP deployment in the U.S. residential sector, resulting in fewer than 1,000 total installed units⁴, or a deployment rate of less than 0.002%. In order to fundamentally change this dynamic, ARPA-E believes that an efficiency of at least 40% and a system cost of less than \$3,000 per kW_e is needed. The ARPA-E GENSETS program seeks new engine (generator) technologies to enable widespread deployment of CHP, primarily for the residential sector. However, if successful, it is anticipated that the same technologies could be readily scaled up to enable extensive CHP implementation in the commercial sector. Roughly 70 million U.S. residential homes² currently have access to natural gas, critical for widespread CHP deployment. To enable residential CHP adoption, ARPA-E believes that inexpensive, efficient, small-scale generators are the key enabler.

2.2 The Optimal CHP System

Optimal Size and Efficiency

A single size engine/generator will not satisfy every application in a diverse residential CHP market. However, ARPA-E's analysis, presented below, indicates that a 1-kW_e output is optimal for most residential applications.

In order to define an optimal engine/generator size that could be deployed across the entire U.S. residential sector, ARPA-E analyzed the energy consumption profile using the National Renewable Energy Laboratory (NREL) BEopt tool⁵ for twelve representative cities in the seven Building America Climate Regions⁶. For example, Figure 2 shows the hourly energy consumption/load profile for Chicago (in the cold climate zone) during representative summer and winter days. The green solid line represents the output from a theoretical 1-kW_e generator running at a steady-state all day. In both the January and July cases, a 1-kW_e system would send a small amount of electricity to the grid during the early morning hours and the household would extract electricity from the grid during evening hours to supplement their electricity needs. For most days, the electricity from the 1-kW_e system is slightly below the household needs and hence the household would need to extract a small amount of electricity from the grid.

³ Arghandeh et al. IEEE Power & Energy Magazine, September/October, 2014, p. 76.

⁴ http://arpa-e.energy.gov/sites/default/files/Mike%20Cocking_Marathon.pdf

⁵ <https://beopt.nrel.gov/>

⁶ <http://www.eia.gov/consumption/residential/maps.cfm>

A 1-kW_e 40% electrical efficiency system would generate 1.5 kW per hour of exhaust heat, represented by the light-blue areas enveloped by thin dashed red lines in Figure 2. For Chicago, the exhaust heat would be able to satisfy all the domestic hot water needs and also contribute to space heating requirements during the cold-weather months. Additional space heating could be provided by a natural gas fired furnace, which is likely >80% efficient. In the summer months, the exhaust heat produced from the CHP system is beyond the domestic hot water requirements. However, air conditioning energy saving opportunities could be realized through use of advanced adsorption chillers.

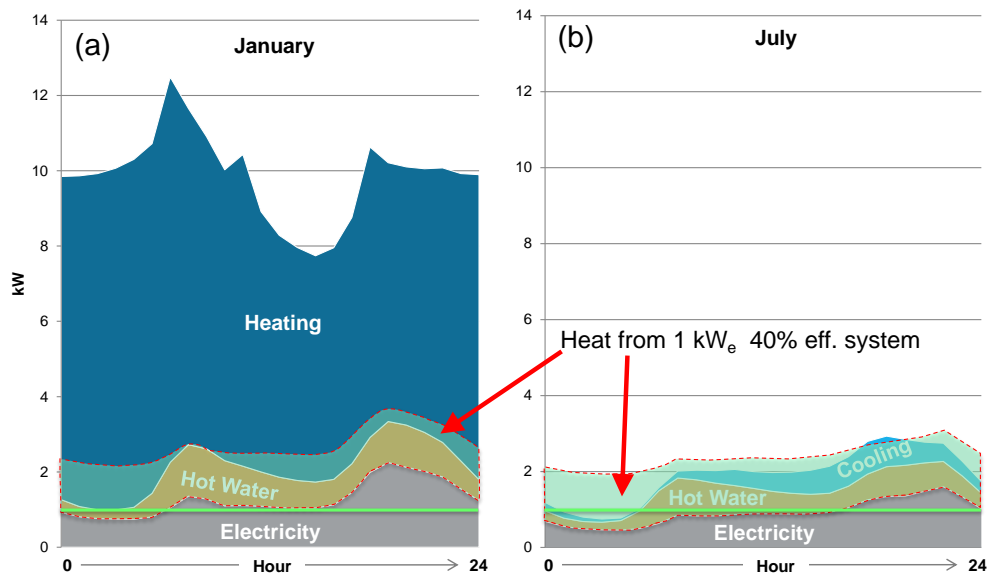


Figure 2. Hourly residential energy consumption profile for Chicago during (a) January and (b) July. The turquoise-colored areas enveloped by the red dashed lines represent the heat output from a 1-kW_e system at 40% electrical efficiency.

Larger CHP systems are unnecessary for ordinary homes in the residential sector and would lead to reduced overall efficiency. First, excess electricity generated by a larger system would need to be delivered to the grid, which may or may not pay retail or even wholesale electricity price depending on the local and the electricity utility policies. Second, systems above 1 kW_e would produce a significant amount of unused exhaust heat during the warm-weather months. This would necessitate the system to operate at a reduced load (which lowers the efficiency) or to operate only in cold weather months (which reduces the capacity factor). Similar conclusions are drawn from ARPA-E's examination of load data for the 11 other cities located across different climate zones⁷. Based on this analysis, ARPA-E has determined that 1-kW_e is an appropriate scale in terms of electrical and thermal output for application across the U.S. and focuses this FOA on developing a generator to provide that output with 40% electrical efficiency.

⁷ http://arpa-e.energy.gov/sites/default/files/JC%20Zhao_Small%20engines%20for%20CHP%20workshop%20Introduction_final.pdf

Minimum System Lifetime and Maximum Viable CAPEX

Reducing total cost of ownership will be a key enabler to CHP system adoption. This FOA focuses primarily on the CAPEX associated with the gas to electrical generation part of the system. The CAPEX defined here includes the system cost but excludes the installation and balance of plant costs. (The balance of plant includes a smart meter and heat exchangers to dissipate excess heat not being used).

ARPA-E performed a techno-economic analysis for a hypothetical residence with an hourly 1 kW electric and 1.5 kW thermal load (both assumed constant for simplicity). The 2013 national average retail price of electricity (\$0.11 per kWh) and natural gas (\$10.85 per thousand cubic feet) were used in the analysis. In this case, a customer would pay about \$1,700 a year to obtain electricity from the grid and natural gas through a pipeline, which serves as the baseline scenario. Replacing this with CHP would require the homeowner to pay the initial labor costs at installation and balance of system costs of ~\$1,400, and an Operation and Maintenance (O&M) cost of roughly \$0.005 per kWh. ARPA-E analysis shows breakeven for the homeowner in 7 years if the 40%-efficient generator system costs about \$3,000 in CAPEX. The homeowner would pay about \$1,240 per year, and would be able to use savings in electricity and natural gas costs to recover the cost of the CHP system and pay ongoing O&M costs.

More analysis was performed by varying the values of CAPEX, lifetime/durability of the system, electricity price, and capacity factor. The results clearly show that even with 40% electrical efficiency, if the system lifetime is below 10 years, it is very hard to compete with today's baseline. A lower CAPEX of \$1,000 would provide a payback period of three years, but ARPA-E recognizes that it is unlikely that a 40%-efficient generator could be produced at such low cost.

ARPA-E recognizes that installing and maintaining the electricity grid requires high fixed-cost investment in wires, transformers, etc. Currently, residential customers pay for these costs predominantly through their \$/kWh retail electricity rates. As the penetration of distributed generation continues to grow, traditional utility rate structures that recover fixed costs through variable rates can cause problems such as utility revenue inadequacy and cross-subsidization between customers. Projecting the actual cost of grid electricity into a future with widespread CHP penetration is highly uncertain, since customers who install CHP systems would continue to rely on a connection from the electrical grid and they will continue to pay a portion of the cost of grid installation and maintenance. A lower bound for comparison would be to use the current wholesale electricity price in the analysis (\$0.06 to \$0.10 per kWh), which with a 7-year payback indicates that the CAPEX would likely need to be below \$2,000 for the 40% generator.

In light of the considerations above, the GENSETS FOA sets a CAPEX target of \$3,000 and a system lifetime of 10 years. These targets provide a fair balance between payback time for the consumer in light of uncertainty in future electricity prices associated with high CHP penetration.

Emissions and Noise Requirements

In order to be widely deployable across the country over time, ARPA-E expects CHP systems to meet the 2007 California Air Resources Board (CARB) emissions regulations for natural gas powered electrical generation technologies in distributed generation applications⁸. The GENSETS targets for emission of nitrogen oxide (NO_x), carbon monoxide (CO) and volatile organic compounds (VOCs) are 0.07, 0.10, and 0.02 lb/MW-hr, respectively.

The GENSETS Program also utilized the Environmental Protection Agency (EPA) New Source Performance Standards (NSPS) on Particulate Matter (PM) to set the limit at 0.4 g/kW-hr⁹. The GENSETS Program also aims at regulating both CO₂ and CH₄ greenhouse gas (GHG) emissions using a CO₂ equivalent (CO₂eq) number that is calculated based on the 100 year global warming potential (GWP) value of 28¹⁰ for CH₄; and the system-out CO₂eq limit is 1100 CO₂eq lb/MW-hr. The acceptable target noise level for customers, who likely would install the CHP systems in their basement, is 55 dB (A-weighting) measured at a 3-foot distance.

2.3 Technical Opportunities, Challenges and State-of-the-Art

Various systems have been commercialized or are in development for CHP applications requiring <5-kW_e, including internal combustion engines (ICEs), external combustion engines such as Stirling engines and Rankine engines, fuel-cells, micro-turbines, and solid state devices such as thermionic generators, thermoelectrics, and thermophotovoltaics (TPV)¹¹.

Table 1 shows best-in-class electrical conversion efficiencies for small-scale CHP applications^{12,13,14}. The heat recovery efficiency is for domestic heating and hot-water. The total CHP efficiency is the sum of the electrical conversion and heat recovery efficiencies.

For a combustion engine, the final electrical efficiency η_e can be written as:

$$\eta_e = \eta_{\text{comb}} \cdot \eta_{\text{ind}} \cdot \eta_m \cdot \eta_{\text{alt}} \quad (\text{Eq. 1})$$

The combustion efficiency η_{comb} represents the portion of the fuel's energy that is converted into useful heat. The indicated cycle efficiency η_{ind} refers to the fraction of the useful heat energy that is converted into closed-cycle work after losses. The mechanical efficiency η_m is the percent of useful closed cycle work that is available at the shaft taking into account friction and parasitic losses. Finally, the alternator efficiency η_{alt} represents the portion of shaft work that is converted into useful electrical power. To reach the 40% η_e target, improvements in the contributing efficiencies in Eq. (1) are sought.

⁸ 17 CCR §94203(b) (California Code of Regulations)

⁹ 40 C.F.R. § 1039.101

¹⁰ <http://www.ipcc.ch/report/ar5/wg1/>

¹¹ http://www.microchap.info/micro_chp_products.htm

¹² Barbieri et al., Applied Energy, V.97, 2012, pp.723-733

¹³ De Paepe et al., Energy Conversion and Management, V.47, 2006, pp. 3435-3446

¹⁴ <http://world.honda.com/news/2011/p110523Gas-Engine-Cogeneration/>

Table 1: State-of-the-art efficiencies of engines for small-scale CHP applications^{12,13,14}

Device/Parameter	ICE	Stirling engine	Micro-turbine	Thermophotovoltaic
Electrical power (kW _e)	1.0	2.0	3.0	1.5
Thermal power (kW)	2.5	8.0	15.0	9.4
Fuel Power (kW)	3.8	10.0	18.8	12.2
Electrical conv. eff. (%)	26.3	20.0	16.0	12.3
Heat recovery eff. (%)	65.7	80.0	80.0	79.8

ARPA-E recognizes there is a significant technology gap between the current state-of-the-art engine fuel to electricity efficiency (~26%) and the 40% target, especially while meeting demands on CAPEX/cost (\$3,000) and system lifetime/durability (10 years). A fundamental challenge in devising small-scale heat engines with high efficiency is minimizing heat losses. With the exception of incomplete combustion, the main losses suffered when converting one form of energy to another are attributable to heat transfer losses. The challenge is significant for 1 kW_e engines where the high surface area to volume ratio leads to increased heat transfer loss. Figure 3 shows a typical small-scale mechanical heat engine efficiency loss breakdown. This figure suggests many methods that will likely be needed to increase the engine efficiency: 1) effective recuperation of the exhaust heat using bottoming cycles; 2) reduced heat transfer through the engine wall using thermal barriers or reduced combustion temperature to reduce the gradient across the wall; 3) effective recuperation of heat transferred to the engine coolant; and 4) reduced frictional loss through better lubrication and other techniques. Additional efficiency gains could also be obtained by reducing the parasitic losses in converters and electronics. Finally, coupling a mechanical engine with a solid state device such as a thermoelectric generator may be necessary to achieve 40% electrical efficiency. Therefore, successful systems may require topping or bottoming cycles as well as potential use of emissions reduction sub-systems. Innovative approaches together with cost-effective manufacturing technologies are needed to achieve the CAPEX target.

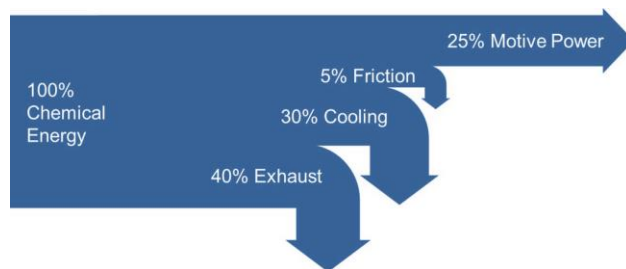


Figure 3. Typical small-scale heat engine efficiency losses.

The subsequent technical examples are meant only to illustrate principles; they are not meant to prescribe or limit the technical approaches that might receive an award through the GENSETS Program. ARPA-E will consider making an award to any application that effectively

addresses the technical challenges and leads to the development of technology that can meet or exceed the associated Technical Performance Targets specified in Section I.E. ARPA-E will make awards only to transformational solutions that go well beyond the state-of-the-art.

Internal Combustion Engines (ICEs)

For generations, ICEs have been the predominant engine for a range of applications and have also penetrated the CHP market. However, ICE efficiencies remain far below the target of this FOA. Nonetheless, there are many potential opportunities for increasing efficiency. For example, the natural gas powered ICE, noted in the second column in Table 1, achieves high efficiency by employing an over-expanded Atkinson cycle and a unique geometric design.¹⁴

Novel strategies for reducing in-cylinder heat transfer¹⁵ and friction¹⁶ and/or novel methodologies for tapping coolant and exhaust heat need to be devised for ICEs to deliver 40% electrical efficiency at the 1-kW_e size. New understanding of combustion science such as boosted homogeneous charge compression ignition (HCCI)¹⁷ and novel implementation of more effective thermodynamic cycles such as Miller cycle and Humphrey cycle may also enable significantly higher efficiencies. Some of the current technologies in this direction are Miller cycle using variable valve timing (VVT)¹⁸, boosted HCCI, advanced Corona ignition system (ACIS)¹⁹, lean natural gas combustion²⁰, low temperature combustion using high exhaust gas recirculation (EGR)²⁰, opposed two-stroke piston engine²¹, free piston linear generator^{22,23,24}, and employment of five-stroke cycle²⁵. It should be noted that above examples do not entail ARPA-E's endorsement of a specific technology but they are listed here to stimulate more ideas/concepts for efficiency enhancements.

Benchmarking experiments by Thomas²⁶ show that, with a three-way catalyst, a 4.7 kW_e ICE CHP system with a fuel to electricity conversion efficiency of 24.7% produces about 0.1 mg/Nm³ of CO and 8.4 mg/Nm³ of NO_x emissions. Boosted HCCI or lean natural gas combustion can increase the electrical efficiency, but that may lead to higher CO and hydrocarbon (HC) emissions as well as higher combustion noise due to increased rates of in-cylinder peak pressure rise. Mitigation of HC and CO emissions can potentially be achieved by using a high-

¹⁵ Chan and Kohr, Journal of Materials Engineering and Performance, V.9, 2000, pp.103-109

¹⁶ http://energy.gov/sites/prod/files/2014/03/f8/deer12_gangopadhyay.pdf

¹⁷ Kobayashi et al., Journal of Natural Gas Science and Engineering, V.3, 2011, pp.651-656

¹⁸ Fontana and Galloni, Applied Energy, V.86, 2009, pp.96-105

¹⁹ Burrows, J., et al., MTZ, V.74, No. 6, 2013, pp.38-41

²⁰ Caton, J.A., Energy Conversion and Management, V.79, 2014, pp.146-160

²¹ http://www.achatespower.com/pdf/light-duty_engine_study.pdf

²² Kosaka, H., Akita, T., Moriya, K., Goto, S. et al. (2014) SAE Technical Paper 2014-01-1203 doi: 10.4271/2014-01-1203

²³ Goto, S., Moriya, K., Kosaka, H., Akita, T. et al. (2014) SAE Technical Paper 2014-01-1193 doi: 10.4271/2014-01-1193

²⁴ Van Blarigan et al. SANDIA Report SAND99-8206, 1998

²⁵ Kéromnès et al., Energy Conversion and Management, V.82, 2014, pp.259-267

²⁶ Thomas, B., Applied Thermal Engineering, V.28, 2008, pp.2049-2054

efficiency oxidation catalyst or a catalytic afterburner. HCCI and lean combustion can reduce system-out NO_x, and additional NO_x reduction can be achieved with the use of EGR, lean NO_x trap (LNT), or selective catalytic reduction (SCR) to meet the emissions standards of the FOA. While the emissions challenge can be overcome, the cost of mitigation needs to be minimized to meet GENSETS targets.

Stirling Engines

Although Stirling engines may be the most mature external combustion engines that have penetrated the CHP market, considerable innovation would be needed to meet the targets of this FOA. As shown in Table 1, the current state-of-the-art small-scale Stirling engines have roughly 20% electrical efficiency.

Realizing 40% electrical efficiency will likely require significant improvements in combustion efficiency and indicated efficiency by lowering the heat losses. Significant improvements in mechanical efficiency will also be needed to achieve the FOA target. Much higher efficiency may be achieved by: 1) increasing the maximum working fluid temperature to 1000 °C or even 1100 °C using state-of-the-art high-temperature alloys^{27,28} and additive manufacturing technology²⁹ – leading to much higher thermodynamic cycle Carnot efficiencies, 2) augmenting the recuperation effectiveness, and 3) reducing the parasitic losses in converters and electronics. ARPA-E strongly encourages innovative concepts that couple a combustion engine such a Stirling engine with a solid state device such as a thermoelectric generator and/or a thermionic emitter to achieve 40% electrical efficiency.

Thomas²⁶ also shows that a 9 kW_e Stirling engine CHP system with a fuel to electricity conversion efficiency of 26.8% produced about 191 mg/Nm³ of CO and 105 mg/Nm³ of NO_x emissions. The system incorporated a flameless oxidation burner³⁰ and a catalyst for emissions reduction. When higher combustion temperatures are to be used to achieve higher Carnot efficiency, both HC and CO emissions can be reduced but the NO_x emissions would increase and may require further exhaust after-treatment such as EGR, combustion gas recirculation (CGR)³¹, SCR, or LNT.

²⁷ Harada, H. Proceedings of the International Gas Turbine Congress 2003 Tokyo, IGTC2003Tokyo KS-2, pp. 1-9.

²⁸ Pollock, T; Tin, S. J. Prop Power, vol. 22, 2006, pp. 361-374.

²⁹ Gibson, et al. Additive Manufacturing Technologies, Springer, 2010.

³⁰ Wünnig, J.G., Thermprocess Symposium, Düsseldorf, 2003 (http://www.flox.com/documents/03_TP.pdf)

³¹ <http://www.sgc.se/ckfinder/userfiles/files/SGC144.pdf>

Micro-Turbines

Micro-turbines are essentially low-powered versions of gas-turbines used in Brayton cycle power plants. Micro-turbine technologies are more mature for applications over 20 kW_e than for the 1-kW_e regime. For applications less than 5 kW_e there are no major commercial products available; however, a prototype 3 kW_e (15 kW thermal output) system for small-scale CHP achieving 16% electrical efficiency and 80% thermal efficiency has been reported and is being commercialized.³² A rig testing by Visser et al.³³ of another 3 kW_e micro-turbine system shows that much of the fuel energy goes into exhaust (47%), and heat, friction and parasitic losses (39.4%). Higher efficiency micro-turbines may be developed by reducing viscous losses (loss due to low Reynold's number flow) in the turbine passages, lower heat losses (loss due to high surface-to-volume ratios), and lower mechanical and parasitic losses. A suite of technologies may be required to achieve this FOA's targets such as new turbine design concepts, high efficiency intake-air recuperation, reduced heat and frictional losses, use of newer materials such as SiC and Si₃N₄^{34,35} to increase the material temperature limit to 1200 °C or higher for enabling higher thermodynamic cycle Carnot efficiencies³⁶, and incorporation of solid state devices and other topping or bottoming cycles such as organic Rankine cycle³⁷.

Only large-capacity turbines have demonstrated CARB 2007 distributed generation emissions compliance³⁸. Micro-turbines may produce higher HC and CO due to inefficient combustion. Higher combustion/gas temperatures will be needed to increase the fuel to electrical conversion efficiency, which will likely result in higher NO_x emissions and thus require further exhaust after-treatment such as EGR, SCR, or LNT. Mitigation of HC and CO can potentially be achieved by using a high-efficiency oxidation catalyst or a catalytic afterburner. Other low NO_x technologies could include the flameless oxidation burner or ultra-low NO_x burner³⁹.

Solid-State Devices

Several solid-state devices are applicable to power generation and CHP systems, and could be used as topping or bottoming cycles on combustion/mechanical engines. Most prominent among these are thermoelectric generators, thermionic emitters, Na/H/O ion expansion electrochemical devices, thermophotovoltaics (TPVs), and pyroelectrics. There are only a handful of demonstrated technologies in engineered systems. Data on one particular TPV system indicates an electrical efficiency of 12.3% for a 1.5 kW_e system with component efficiency of over 15%⁴⁰ as shown in Table 1. Current state-of-the-art efficiencies of solid state

³² <http://www.mtt-eu.com/applications/micro-chp>

³³ Visser et al., ASME Journal of Engineering for Gas Turbines and Power, V.133, 2011, pp.042301-1-042301-8

³⁴ <http://infohouse.p2ric.org/ref/20/19293.pdf>.

³⁵ Singh, M. et al. DOI: 10.1002/9781118144091.ch26 (2011).

³⁶ McDonald and Rogers, Applied Thermal Engineering, V.28, 2008, pp.60-74

³⁷ Mago and Luck, Applied Energy, V.102, 2013, pp.1324-1333

³⁸ <http://www.arb.ca.gov/energy/dg/eo/dg018.pdf>

³⁹ <http://www.energy.ca.gov/2013publications/CEC-500-2013-043/CEC-500-2013-043.pdf>

⁴⁰ http://www.jxcrystals.com/old_TP/V/RomeCHP.pdf

devices have not exceeded 20%, however they possess significant potential for achieving higher efficiencies with newer materials, architectures, and manufacturing processes^{41,42,43}. As mentioned before, they can also play a significant role in reaching high overall system efficiency by serving as either a topping or a bottoming cycle to another device/engine.

The emissions and noise challenges for solid state devices are essentially the same as the Stirling engines where natural gas combustion is used to generate heat to be converted to electricity in these devices.

C. PROGRAM OBJECTIVES

As seen in Section I.B of this FOA, all the current state-of-the-art engines for CHP suffer from low efficiency and high cost. The ARPA-E GENSETS program is seeking fundamentally disruptive technologies that can markedly improve the fuel to electricity efficiency to 40% while delivering 1 kW_e electrical power at low cost. The total system cost should not exceed \$3,000 at high volume (e.g., 1 million unit scale) (excluding \$1,400 installation and balance of plant costs). These technologies must meet the emissions requirements documented in detail in Section I.E of this FOA. The key program objectives are outlined below in detail:

Achieve 40% fuel-to-electrical power generation efficiency

The goal of the ARPA-E GENSETS program is to leverage existing technologies and encourage disruptive concepts that can realize the 40% electrical efficiency target and deliver low cost 1 kW_e systems for residential CHP applications.

Comply with emissions standards

As described above, widespread deployment of CHP systems would result in significant reduction in CO₂ emissions as compared to central-station power plants. However, significant challenges exist in reducing CO, NO_x and VOCs in natural gas powered CHP systems at the 1 kW_e size. Through the GENSETS FOA, ARPA-E is expecting generator concepts with high combustion efficiencies that produce emissions that comply with both the 2007 CARB emissions regulations on NO_x, CO and VOCs and the EPA NSPS limit on PM. A system-out GHG limit is set at 1100 CO₂eq lb/MW-hr to ensure compliance with prevailing state-level environmental standards.

⁴¹ <http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/19252/1/98-0546.pdf>

⁴² Caillat et al., Nuclear and Emerging Technologies for Space, 2012
(<http://www.lpi.usra.edu/meetings/nets2012/pdf/3077.pdf>)

⁴³ Lee et al., Applied Thermal Engineering, V.37, 2012, pp.30-37

Achieve long lifetime/durability

The target for the total system life is 10 years with a capacity factor of 99.9%, i.e., the system should have the capability of running continuously between services (e.g., oil change or cathode replacement) which should not be more than once a year, corresponding to about 8,000 running hours between service intervals. Based upon reported performance, this is a realistic goal to achieve for ICEs and Stirling engines. For example, for a 1 kW_e CHP system,¹⁴ a manufacturer reports 6,000 running hours or 3 years between service, which is close to the target set by this FOA. Also, a Stirling engine manufacturer has demonstrated maintenance-free operation for 100,000 hours (11 years) and eight other engines have more than 8,000 hours and are still running. The system lifetime target will be a challenge for new device types that are still rapidly-evolving in design such as solid state devices and micro-turbines. Accelerated testing should be used by GENSETS performers to project actual field lifetimes from shorter duration test data.

Reduce system cost to enable widespread penetration of residential CHP

The total CAPEX here includes the system cost but excludes the installation and balance of plant costs. The CAPEX target for the 1 kW_e system is no more than \$3,000.

D. TECHNICAL CATEGORIES OF INTEREST

The ARPA-E GENSETS program will fund transformational technologies that can create a paradigm shift in the residential heat and power generation process. ARPA-E expects GENSETS to open pathways for high-efficiency, low-emissions, long-life, cost-effective, 1-kW_e generators that can enable significant energy savings and CO₂ emissions reduction.

Applicants must present a well-justified, realistic proposal for the design, construction, and demonstration of a complete engine/generator system that meets all the technical performance targets. Specifically, the systems should accept natural gas at standard residential delivery pressures as their only fuel input and produce 60 Hz ac electrical output at 110 V.⁴⁴

Example technologies of interest, either as standalone solutions or in combinations, include, but are not limited to:

- Internal combustion engines
- External combustion engines such as Stirling engines and steam engines
- Any other novel engines (e.g. detonation engines, thermoacoustic engines, free-piston engines, rotary engines etc.)
- Combustion turbines such as micro-turbines
- Micro Rankine cycles

⁴⁴ The proposed systems are not required to meet all grid interconnection requirements. However, applicants should explain in the full proposal how low power quality output can be made compatible with grid requirements.

- Novel concepts that incorporate exhaust and coolant waste-heat recovery, reduced mechanical friction and reduced heat transfer
- Novel concepts to improve combustion efficiency and emissions reduction such as exhaust gas recirculation (EGR) or flue gas recirculation (FGR), homogeneous charge compression ignition (HCCI), spark-assisted HCCI (SA-HCCI), corona ignition, and laser ignition
- Thermophotovoltaics
- Thermionic emitters
- Thermoelectric generators
- Pyroelectrics
- Ion expansion electrochemical devices for electricity generation
- Innovative integration of topping cycles and/or bottoming cycles
- Combinations of the above devices and concepts

E. TECHNICAL PERFORMANCE TARGETS

Only technologies with potential to meet or exceed all GENSETS primary targets will be considered for funding. Program teams must propose to meet the following primary targets and will need to demonstrate these targets by the end of the award period.

Number	Property	Primary Target
1.1	Electric power generation capacity	1 kW _e
1.2	Fuel to electricity conversion efficiency	≥40%
1.3	Useful heat energy output (> 80°C)	>1 kW/kW _e
1.4	Capacity factor	≥99.9%
1.5	Complete system up front cost (not including balance of plant and installation)	≤\$3000/kW _e
1.6	Lifetime	≥10 years
1.7	Total system-out NO _x	≤0.07 lb/MW-hr
1.8	Total system-out CO	≤0.10 lb/MW-hr
1.9	Total system-out VOC	≤0.02 lb/MW-hr
1.10	Total system-out CO ₂ eq (CO ₂ + CH ₄ only)	≤1100 lb/MW-hr
1.11	Particulate matter (PM)	≤0.4 g/kW-hr
1.12	System noise	≤55 dB(A) (3-feet away)

In addition, technologies should propose to meet the following secondary targets:

Number	Property	Secondary Target
1.13	Methane number for operation	≥ 70
1.14	Number of regular maintenance services	$\leq 1/\text{year}$
1.15	Operation and maintenance cost	$\leq \$0.005/\text{kWh}$
1.16	Time for regular maintenance	$\leq 60 \text{ minutes/service}$
1.17	System mass	$\leq 150 \text{ kg}$

Supplementary Explanations of Targets

- 1.1 The system concept should target 1-kW_e generation. However, if the efficiency target is demonstrated in a device which has < 1-kW_e power producing capacity, then a detailed scaling analysis should be presented to project efficiency at 1-kW_e. Systems larger than 1-kW_e are not of interest.
- 1.2 Natural gas fuel to ac electricity conversion efficiency is based on lower heating value (LHV) of pipeline natural gas with 983 Btu per cubic foot. Individual component efficiencies of 40% are not sufficient. A device delivering 40% electrical efficiency relative to its input heat energy is not acceptable. Solid-state devices should be treated as external combustion engines and electrical efficiency should be described as in Eq. 1 ($\eta_e = \eta_{\text{comb}} \cdot \eta_{\text{ind}} \cdot \eta_m \cdot \eta_{\text{alt}}$).
- 1.3 Residential hot-water and space heating output provided by CHP system should be > 1 kW/kW_e at > 80 °C.
- 1.4 The system is expected to run continuously between the scheduled regular maintenance and restart easily. 1.5
- 1.5 The engine/generator system, including emissions mitigation and dissipation of exhaust heat (when not fully used), must plausibly cost less than \$3,000 per kW_e in large production volumes (e.g., one million units). The \$3,000 cost of the generator system itself includes all components needed to take pipeline natural gas and produce electricity (ac, 60 Hz) and exhaust heat as outputs; the costs of installation (labor) and balance of plants (smart meters and heat exchangers for integration with other systems) of ~\$1,400 are not included. An alternator efficiency (η_{alt}) of 0.8 to 0.96 can be assumed for the purpose of FOA application if the alternator is not integral to the generator under development. The alternator cost needs to be included in the system CAPEX. The cost of commercially available alternators varies essentially linearly as the efficiency increases from 0.8 to 0.96 according to: Alternator cost [\$] = 3250* η_{alt} – 2520. Systems that do not need an alternator can exclude this cost.

- 1.7-1.9 Emissions for NO_x, CO and VOCs should comply with CARB 2007 emissions limits for distributed power generation. Concept papers should briefly address needed strategies for limiting emissions. Full applications must provide a more complete discussion relative to the state-of-the-art numbers in a specific category of technology (e.g. ICE) and how improvements are made with respect to the baseline performance in the literature. Mitigation technologies are allowable as long as the cost is included in the system CAPEX.
- 1.10 For GHG emissions, only CO₂ and CH₄ are considered by the GENSETS Program. CO₂eq value for CH₄ must be evaluated using its 100 year GWP value of 28, i.e., 1 g of CH₄ corresponds to 28 g of CO₂eq. The total system-out CO₂eq must be less than 1100 lb/MW-hr.
- 1.13 The system must be able to operate at methane numbers as low as 70. Methane number is defined using the following equations⁴⁵:
- $$\text{Motor octane number (MON)} = -406.14 + 508.04 \cdot (\text{H/C}) - 173.55 \cdot (\text{H/C})^2 + 20.17 \cdot (\text{H/C})^3$$
- Methane number (MN) = 1.624 * MON – 119.1. H/C is the fuel hydrogen to carbon ratio.
- A Wobbe index⁴⁶ of 1328 ±8% is allowed to accommodate different natural gas compositions.

F. 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 Section I.E of the FOA
- 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 solely at discovery and/or 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).

⁴⁵ <http://www.arb.ca.gov/regact/cng-lpg/appd.pdf>

⁴⁶ https://www.naesb.org/pdf2/wgq_bps100605w2.pdf

- Applications for proposed technologies that are not transformational, as described in Section I.A of the FOA and as illustrated in Figure 1 in Section I.A of the FOA.
- 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.
- Applications that propose the following:
 - CHP systems that employ fuel cells (ARPA-E has previously solicited for innovative fuel cell technology for distributed generation applications through its REBELS FOA)
 - Internal and external combustion systems that are powered by fuels other than natural gas, e.g., gasoline and diesel engines.
 - Employment of dual-fuel combustion such as diesel/natural gas fuel blends
 - Concepts with more than 1-kW_e power generation capacity

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately \$25 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 12-18 awards under this FOA. ARPA-E may issue one, multiple, or no awards.

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

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be ~~OCTOBER~~ **AUGUST** 2015, or as negotiated.

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

Applications requiring proof-of-concept R&D can propose a project with the goal of delivering on the program metric at the conclusion of the project period. These applications should contain an appropriate cost and project duration plan that is described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. If awarded, such projects should expect a rigorous go/no-go milestone early in the project associated with the proof-of-concept demonstration.

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

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

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

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."⁴⁷ 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.⁴⁸

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

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

⁴⁷ U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).

⁴⁸ The Prime Recipient is the signatory to the funding agreement with ARPA-E.

2. FUNDING AGREEMENTS WITH FFRDCs, GOGOs, AND FEDERAL INSTRUMENTALITIES⁴⁹

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 & Disclosures 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.

When a FFRDC is a *member* of a Project Team, ARPA-E generally 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 Prime Recipient under the Cooperative Agreement is the lead organization for the entire project, including all work performed by the FFRDC 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 will have substantially similar terms and conditions as ARPA-E’s Model Cooperative Agreement (<http://arpa-e.energy.gov/arpa-e-site-page/award-guidance>).

Non-DOE GOGOs and Federal agencies may be proposed as supporting project team members on an applicant’s project. The Non-DOE GOGO/Agency support would be obtained via an Interagency Agreement between ARPA-E and the non-DOE GOGO/Agency, and provided as part of ARPA-E’s standard substantial involvement in its funded projects.

⁴⁹ DOE/NNSA GOGOs are not eligible to apply for funding, as described in Section III.A of the FOA.

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. See 10 C.F.R. § 603.105 for a description of a TIA.

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 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 and Prime Recipients mutually 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/arpa-e-site-page/award-guidance>). 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 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 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.

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,⁵⁰ as the lead for a Project Team,⁵¹ or as a member of a Project Team.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits⁵² 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.

⁵⁰ A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.

⁵¹ 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.

⁵² Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

State 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 United States (including U.S. territories). The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

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

Unincorporated consortia must provide the Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This 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 SHARING⁵³

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

1. BASE COST SHARE REQUIREMENT

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement **or Grant**, the Prime Recipient must provide at least 20% of the Total Project Cost⁵⁴ as cost share, except as provided in Sections III.B.2 or III.B.3 below.⁵⁵

2. INCREASED COST SHARE REQUIREMENT

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

Under 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.
- Small businesses – or consortia of small businesses - will provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the “Cost Share Grace Period”).⁵⁶ If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs

⁵³ Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.

⁵⁴ The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs and FFRDCs.

⁵⁵ Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

⁵⁶ Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration’s (SBA) “Table of Small Business Size Standards Matched to North American Industry Classification System Codes” (NAICS) (<http://www.sba.gov/content/small-business-size-standards>).

incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80%, but less than 100%, of the total work under the funding agreement (as measured by the Total Project Cost) the Project Team are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.⁵⁷
- 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, small businesses 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.

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.

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.

⁵⁷ See the information provided in previous footnote.

5. COST SHARE ALLOCATION

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

6. COST SHARE TYPES AND ALLOWABILITY

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G.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) funds⁵⁸ 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.

⁵⁸ As defined in Federal Acquisition Regulation Section 31.205-18.

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

~~Applicants may wish to refer to 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.~~

Applicants may wish to refer to 2 C.F.R. Parts 200 and 910, and 10 C.F.R Part 603 for additional guidance on cost sharing, specifically 2 C.F.R. §§ 200.206 and 910.130, and 10 C.F.R. §§ 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCs AND GOGOs

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

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

8. COST SHARE VERIFICATION

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

- The Applicant meets the eligibility requirements in Section III.A of the FOA;
- The Concept Paper complies with the content and form requirements in Section IV.C of the FOA; and

- The Applicant entered all required information, successfully uploaded all required documents, and clicked the “Submit” button in ARPA-E eXCHANGE by the deadline stated in the FOA.

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. 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 SF-424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully 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.F 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 in Section V.A.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

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

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

5. PRE-SELECTION CLARIFICATIONS AND “DOWN-SELECT” PROCESS

Once ARPA-E completes its review of Full Applications and Replies to Reviewer Comments, it may, at the Contracting Officer’s discretion, conduct a pre-selection clarification process and/or perform a “down-select” of Full Applications. Through the pre-selection clarification process or down-select process, ARPA-E may obtain additional information from select Applicants through pre-selection meetings, webinars, videoconferences, conference calls, 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. The Selection Official may select or not select a Full Application for award negotiations. The Selection Official may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

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

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, and Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures 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 Summary Slide, the template for the Summary for Public Release, and the template for the Reply to Reviewer Comments.

C. CONTENT AND FORM OF CONCEPT PAPERS

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

- The Concept Paper must not exceed 4 pages in length including graphics, figures, and/or tables.

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

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.

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

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

1. CONCEPT PAPER CONTENT

a. CONCEPT SUMMARY/OVERVIEW

- Provide a concise description of the proposed concept with minimal jargon, explain the innovations relative to the state-of-the-art, and how the proposed effort represents a transformational and potentially disruptive solution to the technical targets in Section I.E of the FOA.
- Include a descriptive schematic of the proposed innovative concept with various key components and rough dimensions of the system.
- Include a fuel to electrical conversion system efficiency cascade of the entire system similar to the one prescribed in Eq. 1 ($\eta_e = \eta_{\text{comb}} \cdot \eta_{\text{ind}} \cdot \eta_m \cdot \eta_{\text{alt}}$) of the FOA, and address the pathway for attaining the 40% fuel to (ac) electricity conversion efficiency target [For solid-state devices, combustion efficiency should be included in the overall efficiency equation when heat is used as input to the devices].

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

- Include a brief description of the emissions mitigation strategy for meeting the emissions targets as described in Section I.E. of the FOA.
- Provide a brief statement about the system cost, including all components of the systems such as an alternator and emissions mitigation subsystem if used.

b. PROPOSED WORK

- Describe the overall technical approach to be used to achieve project objectives.
- Describe concisely the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach; include appropriate citations wherever necessary.
- Describe why the proposed effort is a significant technical challenge and highlight the key technical risks; explain whether the approach requires one or more entirely new technical developments to succeed and how will the technical risks be mitigated; and list two components in the system that will likely be the first to fail during long-term operation.

c. TEAM ORGANIZATIONS AND CAPABILITIES

- List key personnel and partner organizations and their roles in the project team.
- Describe the capabilities and experiences of the team in designing and fabricating the various key innovative components of the proposed systems.
- Specify the proposed funding and the proposed budget for each organization.

2. ADDITIONAL INSTRUCTIONS

- Do not justify your project in terms of energy-savings, CO₂ reductions, and other benefits of CHP as ARPA-E is already well aware of these benefits. Focus your Concept Paper on describing what innovations your team brings to achieve the technical targets specified in Section I.E of the FOA.
- Do not compare different technology types; compare only to the state-of-the-art within a technology type. For example, an application proposing a Stirling engine should compare to other Stirling engines and not to internal combustion engines.

- Use of the term “no moving parts” alone is insufficient to justify durability and long lifetime, as systems with no moving parts do not necessarily last longer than those with moving parts. Identify the failure modes of the proposed system and justify why it can attain the lifetime target.

D. CONTENT AND FORM OF FULL APPLICATIONS

~~[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]~~

Full Applications must conform to the following formatting requirements:

- Each document must be submitted in the file format prescribed below.
- The Full Application must be written in English.
- All pages must be formatted to fit on 8-1/2 by 11 inch paper with margins not less than one inch on every side. Single space all text and use Times New Roman typeface, a black font color, and a font size of 12 point or larger (except in figures and tables).
- The ARPA-E assigned Control Number, the Lead Organization Name, and the Principal Investigator’s Last Name must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.

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.

Fillable Full Application template documents are available on ARPA-E eXCHANGE at <https://arpa-e-foa.energy.gov>.

Full Applications must conform to the content requirements described below.

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. A Technical Volume template is available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).
SF-424	PDF	Application for Federal Assistance (https://arpa-e-foa.energy.gov). Applicants are responsible for ensuring that the proposed costs listed in eXCHANGE match those listed on forms SF-424 and SF-424A. Inconsistent submissions may impact ARPA-E's final award determination.
Budget Justification Workbook/SF-424A	XLS	Budget Information – Non-Construction Programs (https://arpa-e-foa.energy.gov)
Summary for Public Release	PDF	Short summary of the proposed R&D project. Intended for public release. A Summary for Public Release template is available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).
Summary Slide	PPT	A four-panel project slide summarizing different aspects of the proposed R&D project. A Summary Slide template is available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).
Business Assurances & Disclosures Form	PDF	Requires the Applicant to make responsibility disclosures and disclose potential conflicts of interest within the Project Team. Requires the Applicant to describe the additionality and risks associated with the proposed project, disclose applications for funding currently pending with Federal and non-Federal entities, and disclose funding from Federal and non-Federal entities for work in the same technology area as the proposed R&D project. 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 waiver or modification of the Performance of Work in the United States requirement and/or the Technology Transfer & Outreach (TT&O) spending requirement. This form is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov . A sample response to the Business Assurances & Disclosures Form is also available on ARPA-E eXCHANGE.

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 specified below. If Applicants exceed the maximum page lengths specified for each section indicated below, ARPA-E will review only the authorized number of pages and disregard any additional pages.

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

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).

PAGE LIMIT	SECTION	DESCRIPTION
1 page max.	EXECUTIVE SUMMARY	<p>Summarize the objective(s) and technical approach of the proposed effort at a technical level appropriate for scientific and engineering peers.</p> <p>INSTRUCTIONS:</p> <ol style="list-style-type: none"> (1) The Project Title should be brief and descriptive of the proposed technology. (2) Enter the estimated Total Project Cost in U.S. dollars and percentage cost share in parentheses. (3) Enter the Project Duration in months. (4) The Executive Summary shall not exceed 1 page in length (5) The Executive Summary may contain graphics, figures, or tables as needed to summarize the technical concept.
Sections 1-5 30 pages max.	Section 1 INNOVATION	<p>Describe how the proposed work offers an innovative approach to achieve the program objectives of the FOA.</p> <p>1.1 Overall Description.</p> <ul style="list-style-type: none"> Describe the conceptual basis for the project and how the proposed technology works with minimal jargon. Explain the objective(s) and performance characteristics of the proposed effort. Include a descriptive schematic of the proposed innovative concept with various key components and rough dimensions of the system. Include a fuel to electrical conversion system efficiency cascade of the entire system similar to the one prescribed in Eq. 1 ($\eta_e = \eta_{comb} \cdot \eta_{ind} \cdot \eta_m \cdot \eta_{alt}$) of the FOA, and address the pathway for attaining the 40% fuel to (ac) electricity conversion efficiency target [For solid-state devices, combustion efficiency must be included in the overall efficiency equation when heat is used as input to the devices]. Include a description of the emissions mitigation strategy for meeting the emissions targets as described in Section I.E of the FOA. The CH₄ mitigation strategy must be clearly laid out in the Full Application. <p>1.2 Innovativeness.</p> <ul style="list-style-type: none"> Describe how the proposed effort represents a new and innovative solution to the overall program challenge described in the FOA. Indicate the technical goals and anticipated results, using

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

		<p>appropriate metrics, for the project. Provide a description of how the metrics were derived, citing key previous results and/or assumptions.</p> <ul style="list-style-type: none">• Include and discuss, as appropriate, a table in which the targeted performance of the proposed technology is compared with the “Technical Performance Targets” in Section I.E of the FOA. <p>INSTRUCTIONS:</p> <p>(1) The Innovation Section may include figures, tables, and graphics.</p> <p>(2) The suggested length of the Innovation Section is 4 pages.</p> <p>(3) Do not justify your project in terms of energy-savings, CO2 reductions, and other benefits of CHP as ARPA-E is already well aware of these benefits. Full Applications must describe what innovations the project team brings to achieve the technical targets specified in Section I.E of the FOA.</p> <p>(4) Do not compare different technology types; compare only to the state-of-the-art within a technology type. For example, an application proposing a Stirling engine should only compare to other Stirling engines and not to internal combustion engines.</p> <p>(5) Use of the term "no moving parts" alone is insufficient to justify durability and long lifetime, as systems with no moving parts do not necessarily last longer than those with moving parts. Identify the failure modes of the proposed system and justify why it can attain the lifetime target.</p>
	Section 2 PROPOSED WORK	<p>Describe and discuss for the proposed effort the technical background and approach, the R&D tasks, and the key technical risks. This Section should justify the proposed approach as being appropriate to achieve the project’s objective(s).</p> <p>2.1 Approach.</p> <ul style="list-style-type: none">• Describe the technical approach and how this approach will achieve the proposed project objective(s).• Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support achieving the project objective(s). Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.• A thermodynamic modeling analysis (0-D or higher) is highly recommended to obtain the analytical fuel to electrical conversion efficiency of the generator system. If the model predicted efficiency is lower than the 40% target in Section I.E of the FOA, then a technical discussion showing the pathway to overcome the efficiency deficit is necessary.

		<ul style="list-style-type: none"> Most engine concepts can add a standard thermoelectric generator (~3% efficiency) to boost the system efficiency to the 40% target in Section I.E of the FOA. Applicants are allowed to focus on primary generator technologies only with a fuel to electricity efficiency target of 37% and a cost target of \$2,700 for the 1 kW_e system (assuming 3% efficiency gain from the thermoelectric generator at a cost of \$300). <p>2.2 Technical Risk.</p> <ul style="list-style-type: none"> Identify potential technical issues and risks, e.g., the approach requires a never-before-demonstrated fabrication technique or greater-than-previously-demonstrated sub-component performance, etc. Describe appropriate mitigation techniques and plans, if any, for each identified issue and risk. A Design Fault Mode and Effect Analysis (DFMEA) table or a Fault Tree Analysis (FTA) chart for the entire CHP system must be included. This should clearly identify failure modes and mechanisms, and propose mitigation solutions. The system life capability of 10 years or more must be demonstrated via accelerated life testing (ALT). The procedure (thermal cycling or load cycling) for conducting such a test and appropriate references based on which the ALT procedure was selected must be provided in the Full Application. Full Applications with topping and bottoming cycles (e.g. IC engine with thermoelectric generator) must address ALT for both the technologies. In this case, each individual technology can be treated as a separate component. <p>2.3 Schedule.</p> <ul style="list-style-type: none"> Provide a schedule for the proposed effort by major tasks, including major milestones or Go/No-Go decision points as appropriate. (<u>A Gantt chart is recommended.</u>) The schedule should include a milestone for the delivery of a 1-kW_e prototype at the end of the second project year which will be subjected to independent testing. This prototype need not meet the final deliverable milestones for the project. <p>2.4 Task Descriptions.</p> <ul style="list-style-type: none"> Identify and provide a full technical description for each main task in the proposed effort. Discuss the reason the identified tasks are appropriate and sufficient for the identified approach. Describe the key technical milestones and how these define the critical path for successful completion of the task.
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		<ul style="list-style-type: none">Indicate how completion of each task relates to reducing technological uncertainty and achieving the overall project objective(s). <p>INSTRUCTIONS:</p> <p>(1) The Proposed Work Section may include figures, tables, and graphics.</p> <p>(2) The suggested length of the Proposed Work Section is 12 pages.</p>
	Section 3 TEAM ORGANIZATION AND CAPABILITIES	<p>Describe and discuss the, organization, capabilities, and management of the team and how these enable successful execution of the proposed effort.</p> <p>3.1 Organization.</p> <ul style="list-style-type: none">Indicate roles and responsibilities of the organizations on the proposed Project Team, e.g., subrecipient, consultant, subcontractor, or lead organization for each of the project tasks. Include relevant organization charts and teaming organization charts, as applicable.Identify Key Personnel, describe how their qualifications relate to the proposed effort, and indicate their roles and responsibilities for each of the project tasks.Identify previous collaborative efforts among team members if relevant to the proposed effort. <p>3.2 Capabilities, Facilities, Equipment, and Information.</p> <ul style="list-style-type: none">Identify capabilities of the Applicant or proposed Project Team, e.g., relevant experience, previous or current R&D efforts, or related government or commercial projects, that support the proposed effort.Identify all required facilities, equipment, and information for the proposed effort and discuss their adequacy and availability. <p>Indicate any key equipment that must be fabricated or purchased</p> <p>INSTRUCTIONS:</p> <p>(1) This Section may include figures, tables, and graphics.</p> <p>(2) The suggested length of the Team Section is 4 pages.</p>
	Section 4 TECHNOLOGY TO MARKET	<p>The significant impact sought by ARPA-E depends upon successful projects finding a path to large-scale adoption. ARPA-E projects are not required to achieve commercial deployment by the end of the project period, but the agency asks the applicant to define a reasonable path for the proposed technology toward commercial adoption.</p> <p>4.1 Technology to Market Strategy.</p> <ul style="list-style-type: none">Describe how the proposed technology is expected to transition from the lab to commercial deployment, including a description of the eventual product, potential near- and long-term market entries, likely commercialization approach (startup, license, etc.), specific

		<p>organizations expected to be involved in the transition (partners, customers, etc.), and the commercialization timeline.</p> <ul style="list-style-type: none"> • Discuss manufacturing, cost, and scalability risks associated with the technology. • Describe anticipated resource needs for the next phase of development following the end of the ARPA-E project. • Explain why the proposed research is not being pursued by industry today. • Discuss the anticipated roles for the proposed research team in the commercialization of the technology. <p>4.2 Intellectual Property.</p> <ul style="list-style-type: none"> • Describe existing intellectual property, if any, that will be used to develop the new intellectual property; and • Discuss new intellectual property and data that is anticipated to be created as part of this effort, if any. <p>INSTRUCTIONS:</p> <p>(1) The Technology to Market Section may include figures, tables, and graphics.</p> <p>(2) The suggested length of the Technology to Market Section is 4 pages.</p>																																										
	<p>Section 5 BUDGET</p>	<p>Indicate the budget, in US dollars, and provide a high-level budget summary, demonstrating that the budget is reasonable and appropriate for the proposed effort.</p> <p>5.1 Budget Breakdown.</p> <p>Provide in tabular form following the template give below, a breakdown of the project budget by entity and major task in US dollars.</p> <table border="1"> <thead> <tr> <th>Task Name</th> <th>[Prime]</th> <th>[Sub #1]</th> <th>[Sub #2]</th> <th>[Sub #3]</th> <th>[Sub #4]</th> <th>Total</th> </tr> </thead> <tbody> <tr> <td>[Task #1]</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>[Task #2]</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>[Task #3]</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>[Task #4]</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Total</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table> <p>Replace “Prime” with name of the primary (lead) entity and “Sub #n” with the name of the sub-recipient or sub-contractor entities, if applicable. Task names should clearly correspond to major tasks listed in Section 2.4. Expand or contract the table as needed to add/subtract entities (columns) or tasks (rows).</p>	Task Name	[Prime]	[Sub #1]	[Sub #2]	[Sub #3]	[Sub #4]	Total	[Task #1]							[Task #2]							[Task #3]							[Task #4]							Total						
Task Name	[Prime]	[Sub #1]	[Sub #2]	[Sub #3]	[Sub #4]	Total																																						
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		<p>5.2 Budget Summary.</p> <p>Provide a high-level summary for the project by major budget category, including at least these three:</p> <ul style="list-style-type: none"> • Key Personnel and technical staff to be utilized (e.g., scientists, engineers, technicians, postdocs, graduate students, etc.) • Equipment • Materials and Supplies <p>5.3 Cost Share.</p> <p>Provide a description of the cost share by value of the contribution (in dollars) and percentage of the Total Project Cost (TPC):</p> <ul style="list-style-type: none"> • List each source of cost share, the type of contribution (cash or in-kind), the value of the contribution (in dollars), and the value as a percentage of TPC. • For all in-kind contributions, provide a detailed description of the contribution and its relevance to the project objectives <p>INSTRUCTIONS:</p> <p>(1) The Budget Section may include figures, tables, and graphics. (2) The suggested length of the Budget Section is 4 pages.</p>
No page limit	REFERENCES	<p>Provide a list of references appropriate to Sections 1-5.</p> <p>INSTRUCTIONS:</p> <p>(1) Only bibliographic information may be contained in the references. No additional text or commentary is allowed. (2) There is no page limit for the Bibliographic References Section, which is outside of the overall 30-page limit for Sections 1-5.</p>
Each PQS limited to 3 pages in length, no cumulative page limit	PERSONAL QUALIFICATION SUMMARIES	<p>A Personal Qualification Summary (PQS) is required for the PI and all other Key Personnel. Each PQS must include a description of the following only:</p> <ul style="list-style-type: none"> • Education and training • Employment history • Awards and honors • A list of no more than 10 peer-reviewed publications related to the proposed project • A list of no more than 10 other peer-reviewed publications demonstrating capabilities in the broad field • A list of no more than 10 non-peer-reviewed publications and patents demonstrating capabilities in the broad field

		INSTRUCTIONS: (1) Each Personal Qualification Summary is limited to 3 pages in length and there is no page limit for this Section, which is outside of the 30-page limit for Sections 1-5. (2) Curriculum Vitae should not be submitted.
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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/sflllin.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 August 2015 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>.
- 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.
- Applicants are responsible for ensuring that the proposed costs listed in eXCHANGE match those listed on forms SF-424 and SF-424A. Inconsistent submissions may impact ARPA-E's final award determination.

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 should 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 Section 2.4 Task Descriptions of the Technical Volume.
- For pricing purposes, assume a project start date of [date], 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: SUMMARY FOR PUBLIC RELEASE

Applicants are required to provide a 250 word max. 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.

250 Words	SUMMARY FOR PUBLIC RELEASE	<p>Briefly describe the proposed effort, summarize its objective(s) and technical approach, describe its ability to achieve the "Program Objectives" (see Section I.C of the FOA), and indicate its potential impact on "ARPA-E Mission Areas" (see Section I.A of the FOA). The summary should be written at technical level suitable for a high-school science student and is designed for public release.</p> <p>INSTRUCTIONS:</p> <p>(1) The Summary for Public Release <u>shall not exceed 250 words and one paragraph.</u></p> <p>(2) The Summary for Public Release <u>shall consist only of text</u>—no graphics, figures, or tables.</p> <p>(3) For applications selected for award negotiations, the Summary may be used as the basis for a public announcement by ARPA-E; therefore, this Cover Page and Summary should not contain confidential or proprietary information. See Section VIII.E of the FOA for additional information on marking confidential information</p>
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5. FIFTH 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 will be used during ARPA-E's evaluation of Full Applications. A summary slide template and a sample summary slide are available on ARPA-E eXCHANGE (<https://arpa-e-foa.energy.gov>). Summary Slides must conform to the content requirements described below:

- A Technology Summary;
 - Bullet points that describe novel aspects of the proposed technology and technology approach;
- Proposed Targets;
 - Including any important technical performance metrics;
 - Including quantitative descriptions of the proposed targets;
- Any key graphics (illustrations, charts and/or tables) summarizing technology development;
- The project's key idea/takeaway;
- Project title and Principal Investigator information; and
- Requested ARPA-E funds and proposed applicant cost share.

6. SIXTH COMPONENT: BUSINESS ASSURANCES & DISCLOSURES FORM

Applicants are required to complete a Business Assurances & Disclosures 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 & Disclosures Form is also available on ARPA-E eXCHANGE.

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

- Disclose conditions bearing on responsibility, such as criminal convictions and Federal tax liability;
- Disclose potential conflicts of interest within the Project Team;
- 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, 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.”⁵⁹ In accordance with ARPA-E’s statutory mandate, the Applicant is required to:

- Describe the additionality and risks associated with the proposed R&D project;
- Disclose any applications for the same project or related work currently pending with any Federal or non-Federal entities; and
- Disclose all funding for work in the same technology area as the proposed project received from any Federal or non-Federal entity within the last 5 years.

Finally, the Applicant may use the Business Assurances & Disclosures Form to:

- Request authorization to perform some work overseas; and
- Request a waiver of the TT&O spending requirement.

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

~~[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]~~

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>).

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).

⁵⁹ America COMPETES Act, Pub. L. No. 110-69, § 5012 (2007), as amended (codified at 42 U.S.C. § 16538).

- 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">• Applicants may respond to one or more reviewer comments or supplement their Full Application.
Images	1 page maximum	<ul style="list-style-type: none">• Applicants may provide graphs, charts, or other data to respond to reviewer comments or supplement their Full Application.

F. INTERGOVERNMENTAL REVIEW

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

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]

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/arpa-e-site-page/post-award-guidance>.

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 2 C.F.R. Part 200, as modified by 2 C.F.R. Part 910, 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) before incurring any pre-award costs.

Please refer to the “Applicants’ Guide to ARPA-E Award Negotiations” (http://www.arpa-e.energy.gov/sites/default/files/documents/files/Award_Negotiations_Guide081613.pdf) for additional guidance on pre-award costs.

3. PATENT COSTS

For Subject Inventions disclosed to DOE under an award, ARPA-E will reimburse the Prime Recipient – in addition to allowable costs associated with Subject Invention disclosures - up to \$30,000 of expenditures for filing and prosecution of United States patent applications, including international applications (“PCT application”) submitted to the USPTO.

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 & Disclosures 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;
- 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 & Disclosures Form. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the waiver request. ARPA-E 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://www.arpa-e.energy.gov/sites/default/files/documents/files/Award_Negotiations_Guide081613.pdf) for additional guidance on TT&O requirements.

9. LOBBYING

Prime Recipients and Subrecipients may not use any Federal funds, directly or indirectly, to influence or attempt to influence, directly or indirectly, congressional action on any legislative or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. § 1913. This restriction is in addition to those prescribed elsewhere in statute and regulation.

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

- An employee of a Member of Congress.

10. CONFERENCE SPENDING

Prime Recipients and Subrecipients may not use any Federal funds to:

- Defray the cost to the United States Government of a conference held by any Executive branch department, agency, board, commission, or office which is not directly and programmatically related to the purpose for which their ARPA-E award is made and for which the cost to the United States Government is more than \$20,000; or
- To circumvent the required notification by the head of any such Executive Branch department, agency, board, commission, or office to the Inspector General (or senior ethics official for any entity without an Inspector General), of the date, location, and number of employees attending such a conference.

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 received 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 FOA Targets (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 compared to existing or emerging technologies;
- The extent to which the proposed concept is innovative and will achieve the technical performance targets defined in Section I.E of the FOA for the appropriate technology Category in Section I.D of the FOA; 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 the current state-of-the-art.

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

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- The extent to which the Applicant proposes a sound technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches within a particular category of technology (e.g., Stirling engines) and how technical risk will be mitigated;
- The extent to which project outcomes and final deliverables are clearly defined;
- The extent to which the Applicant identifies techno-economic challenges that must be overcome for the proposed technology to be commercially relevant; and
- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among team members supporting the proposed project.

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

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

2. CRITERIA FOR FULL APPLICATIONS

~~[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]~~

Full Applications are evaluated based on the following criteria:

(1) *Impact of the Proposed Technology* (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;
- 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; and
- The extent to which the Applicant proposes a reasonable and effective strategy for transitioning the proposed technology from the laboratory to commercial deployment.

(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 project outcomes and deliverables are clearly defined;
- 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 based upon preliminary data or other background information and sound scientific and engineering practices and principles;
- The extent to which the Applicant proposes a sound technical approach, including appropriately defined technical tasks, to accomplish the proposed R&D objectives; and
- The extent to which the Applicant manages risk, by identifying major technical R&D risks and clearly proposes feasible, effective mitigation strategies.

(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; and
- 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 project schedule, including major milestones is reasonable; and
- The appropriateness of the proposed budget to accomplish the proposed project.

Submissions will not be evaluated against each other since they are not submitted in accordance with a common work statement.

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]

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 FEBRUARY 2015]

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 Contracting Officer by email (ARPA-E-CO@hq.doe.gov) if they have knowledge of a potential conflict of interest or a reasonable belief that a potential conflict exists.

3. ARPA-E SUPPORT CONTRACTOR

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

By submitting an application to ARPA-E, Applicants represent that they are not performing support contractor services for ARPA-E in any capacity and did not obtain the assistance of ARPA-E's support contractor to prepare the application. ARPA-E will not consider any applications that are submitted by or prepared with the assistance of its support contractors.

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

~~[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]~~

ARPA-E expects to announce selections for negotiations in approximately May, 2015 and to execute funding agreements in approximately August, 2015.

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

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

2. CONCEPT PAPER NOTIFICATIONS

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

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

A notification letter encouraging the submission of a Full Application does not authorize the Applicant to commence performance of the project. Please refer to Section IV.G.2 of the FOA for guidance on pre-award costs.

3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]

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://www.arpa-e.energy.gov/sites/default/files/documents/files/Award_Negotiations_Guide081613.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 FEBRUARY 2015]~~

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/>.⁶⁰ 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 obtain a copy of the executed funding agreement. Please refer to <https://www.fedconnect.net/FedConnect/> for registration instructions.

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

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://www.arpa-e.energy.gov/sites/default/files/documents/files/Award_Negotiations_Guide081613.pdf) for guidance on the contents of cost share commitment letters.

4. COST SHARE PAYMENTS⁶¹

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 generally requires Prime Recipients to contribute the cost share amount incrementally over the life of the funding agreement. Small Businesses see Section III.B.3 of the FOA.

Please refer to the "Applicants' Guide to ARPA-E Award Negotiations" (http://www.arpa-e.energy.gov/sites/default/files/documents/files/Award_Negotiations_Guide081613.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.

¹⁹ Please refer to Section III.B of the FOA for guidance on cost share 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 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.

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).⁶² This requirement does not apply to products that are manufactured for use or sale outside the U.S. A.

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).⁶³ 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.

⁶² 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/content/small-business-size-standards>).

⁶³ 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/content/small-business-size-standards>).

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.

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.

9. CORPORATE FELONY CONVICTIONS AND FEDERAL TAX LIABILITY

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

- It is not a corporation that has been convicted of a felony criminal violation under any Federal law within the preceding 24 months; and
- It is not a corporation that has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN FEBRUARY 2015]

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

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

- 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. ARPA-E will promptly respond to emails that raise legitimate, technical issues with ARPA-E eXCHANGE. ARPA-E will refer any questions regarding the FOA to ARPA-E-CO@hq.doe.gov.

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

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

B. DEBRIEFINGS

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

VIII. OTHER INFORMATION

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

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

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

- The rejection of a Concept Paper, Full Application, and/or Reply to Reviewer Comments;
- The termination of award negotiations;
- The modification, suspension, and/or termination of a funding agreement;

- The initiation of debarment proceedings, debarment, and/or a declaration of ineligibility for receipt of Federal contracts, subcontracts, and financial assistance and benefits; and
- Civil and/or criminal penalties.

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.

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. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.

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

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. REGULATIONS APPLICABLE TO RESULTING AWARDS

Effective December 26, 2014, this FOA and any awards made under it will be governed by 2 C.F.R. Part 200, the Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards, as modified by 2 C.F.R. Part 910, the Department of Energy Financial Assistance Rules.

J. 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).

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

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.

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 GOGOs and FFRDCs.

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