**FINANCIAL ASSISTANCE**
**FUNDING OPPORTUNITY ANNOUNCEMENT**

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

# *INNOVATIVE NATURAL-GAS TECHNOLOGIES FOR EFFICIENCY GAIN IN RELIABLE AND AFFORDABLE THERMOCHEMICAL ELECTRICITY-GENERATION (INTEGRATE)*

**Announcement Type: Initial Announcement**
**Funding Opportunity No. DE-FOA-0001797**
**CFDA Number 81.135**

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| **Funding Opportunity Announcement (FOA) Issue Date:** | July 26, 2017 |
| **First Deadline for Questions to ARPA-E-CO@hq.doe.gov:** | 5 PM ET, Friday, September 22, 2017 |
| **Submission Deadline for Concept Papers:** | 5 PM ET, Tuesday, October 3, 2017 |
| **Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:** | 5 PM ET, TBD |
| **Submission Deadline for Full Applications:** | 5 PM ET, TBD |
| **Submission Deadline for Replies to Reviewer Comments:** | 5 PM ET, TBD |
| **Expected Date for Selection Notifications:** | TBD |
| **Total Amount to Be Awarded** | Approximately $20 million for Phase I, 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 $4 million for Phase I. Combined Phase I and II awards are limited to $12 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.

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

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

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## REQUIRED DOCUMENTS CHECKLIST

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

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

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

| SUBMISSION | COMPONENTS | OPTIONAL/ MANDATORY | FOA SECTION | DEADLINE |
|---|---|---|---|---|
| Concept Paper | • Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following:<br>o Concept Summary<br>o Innovation and Impact<br>o Proposed Work<br>o Team Organization and Capabilities | Mandatory | IV.C | 5 PM ET, Tuesday, October 3, 2017 |
| Full Application | [TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018] | Mandatory | IV.D | 5 PM ET, TBD |
| Reply to Reviewer Comments | [TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018] | Optional | IV.E | 5 PM ET, TBD |

# I. FUNDING OPPORTUNITY DESCRIPTION

## A. AGENCY OVERVIEW

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

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

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

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

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

***ARPA-E funds technology with the potential to be disruptive in the marketplace***. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. ARPA-E understands that definitive proof of market disruption takes time, particularly for energy technologies. Therefore, ARPA-E funds the development of technologies that, if technically successful, have the clear disruptive potential, e.g., by demonstrating capability for manufacturing at competitive cost and deployment at scale.

***ARPA-E funds applied research and development.*** The Office of Management and Budget defines "applied research" as "systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met" and defines "development" 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."[1] Applicants interested in receiving financial assistance for basic research should contact the DOE's Office of Science (http://science.energy.gov/). Office of Science national scientific user facilities (http://science.energy.gov/user-facilities/) are open to all researchers, including ARPA-E applicants and awardees. These facilities provide advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, as well as facilities for studying the nanoworld, the environment, and the atmosphere. Projects focused on the improvement of existing technology platforms along defined roadmaps may be appropriate for support through the DOE offices such as: the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy (http://fossil.energy.gov/), the Office of Nuclear Energy (http://www.energy.gov/ne/office-nuclear-energy), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

## B. PROGRAM OVERVIEW

### 1. SUMMARY

The objective of the INTEGRATE Program is to reduce the cost and increase the primary energy efficiency associated with the provision of electric power to commercial and industrial end users. In this program, ARPA-E seeks to develop natural gas-fueled distributed electric generation systems that offer fuel to electric power conversion efficiencies in excess of 70%. The INTEGRATE program will focus on hybrid system designs that integrate a fuel cell with a heat or reactive engine for ultra-high efficiency at competitive costs. This FOA seeks to encourage the development of the enabling technologies that will make these hybrid systems a reality, and a successful INTEGRATE program will provide highly flexible distributed energy technology options with unprecedented efficiency and lower emissions than today's fossil-fuel generated electricity. Furthermore, the technologies that this program seeks to develop are also expected to have broad electric-power-generation and transportation market applications.

[1] OMB Circular A-11 (http://www.whitehouse.gov/sites/default/files/omb/assets/a11_current_year/a11_2014.pdf), Section 84, p. 8.

ARPA-E recognizes the significance of system cost with respect to commercialization; a highly efficient and flexible system must also be economically attractive to customers and manufacturers. Hence, the simultaneous attainment of conversion efficiency and installed cost targets that would yield attractive financial returns for all stakeholders will be the major focus of the INTEGRATE Program.

In pursuit of the above-mentioned economic and environmental benefits, ARPA-E seeks to encourage the development of distributed generation systems of ≥100 kW that have electric efficiencies in excess of 70% on a lower heating value (LHV) basis and an installed cost to the end user of less than $1.8/W. ARPA-E's market analysis suggests that the simultaneous attainment of these efficiency and cost targets could yield a 1 Quad/year annual reduction in the primary energy[2] that our nation uses to generate its electric power. This reduction would translate into a $3B/year fuel cost savings for the US economy.

Additionally, the envisioned hybrid systems technologies would operate in a water neutral manner in that the systems would self-generate any water required for operation. This feature is in stark contrast to the water-based cooling systems utilized in many of our utility-scale thermoelectric power plants. Consequently, a water-savings of 4 billion gallons per day (~1% of our total fresh water withdrawal) would be commensurate with the above-mentioned fuel savings. This water-savings would translate into another $~2B/year in cost savings for the US economy.

In order to accelerate the development of technologies that could enable this unprecedented thermoeconomic performance, ARPA-E is encouraging the development of the requisite system and component technologies. It is anticipated that such technologies would include advanced integrated engine/balance-of-plant (BOP) concepts, advanced fuel cell stack concepts and manufacturing approaches, advanced BOP components (e.g. high temperature heat exchangers), and advanced control system technologies.

## 2. MOTIVATION

In 2015, two-thirds of our nation's electricity was generated from fossil fuels at a net LHV-basis efficiency of 36%. This electricity was then transmitted and distributed through our nation's electric grid at an efficiency of 95%, yielding a net-delivered efficiency of 34%. The wholesale price of this electricity was an estimated $0.04/kWh[3]. However, commercial and industrial customers paid an additional $0.07/kWh and $0.03/kWh[4], respectively, to have this electricity delivered to them via the grid. Lastly, the vast majority of the aforementioned electricity was

[2] https://en.wikipedia.org/wiki/Primary_energy

[3] The average of the EIA-reported wholesale price data in 2015 was $0.04/kWh. https://www.eia.gov/electricity/wholesale/

[4] The US-average commercial and industrial rates for electricity were $0.11/kWh and $0.07/kWh in 2015. https://www.eia.gov/electricity/data.cfm - sales

generated at centrally-located plants with limited opportunities for the productive utilization of the waste heat produced—66% of the fuel LHV—in the generation, transmission, and distribution processes. While the electrification of the US via the centralized-generation model was one of the greatest technical achievements in the 20th century, comparatively speaking, we are a few key technical steps away from the capability to replace at least a portion of this centralized system with a dramatically more efficient and cost-effective distributed model.

### Status Quo

The current US electric system is dominated by large (typically 400 MW and above) central plants whose electricity is delivered to end users via a wired transmission and distribution system that is commonly referred to as the "grid". This model gained prominence in the 1920's through a combination of generation economies of scale and government regulation[5]. However, subsequent regulatory changes[6] and technology advancements (e.g. solar photovoltaics, gas turbines, microturbines, reciprocating engines, and fuel cells) have enabled an emerging distributed alternative. Nevertheless, the penetration of Distributed Generation (DG) technologies for baseload (non-emergency) applications is still limited—with a <4% penetration for industrial customers and a < 1% penetration for commercial customers. However, the commercial penetration has been growing at a 3% annual rate over the past 15 years. The INTEGRATE program seeks to provide economic and environmental benefits at national and individual scales by *dramatically* enhancing the pace at which commercial DG displaces centrally generated fossil-fueled electricity that is generated via less efficient means.

Primary energy sources for US electricity may be sub-divided into three broad categories: nuclear, renewable, and fossil fuels. Fossil fuels are used to generate roughly two-thirds of our nation's electricity[7] and are forecast to continue to be the dominant primary energy source for electricity for the foreseeable future[8]. This expectation is driven by the low Levelized Cost of Electricity (LCOE) that fossil-fueled systems are able to provide due to their very low capital cost. Additionally, their high dispatchability offers additional economic benefits versus their nuclear and renewable competition[9]. However, at the same time, fossil fuels also present environmental challenges – e.g., the emission of $CO_2$, $NO_x$, and $SO_2$ that stems from their use[10].

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[5] Bakke, Gretchen, "The Grid: The Fraying Wires Between Americans and Our Energy Future".
[6] 1978 Public Utilities Regulatory Policy Act (PURPA), etc.
[7] U.S. Energy Information Administration, "Monthly Energy Review (MER)," March 2017. [Online]. Available: https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf. [Accessed 3 April 2017].
[8] U.S. Energy Information Administration, "Energy Information Administration," 5 January 2017. [Online]. Available: https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf. [Accessed 3 April 2017].
[9] U.S. Energy Information Administration, "Energy Information Administration," November 2016. [Online]. Available: https://www.eia.gov/analysis/studies/powerplants/capitalcost/pdf/capcost_assumption.pdf. [Accessed 3 April 2017]
[10] U.S. Energy Information Administration, "Energy Information Administration," November 2016. [Online]. Available: https://www.eia.gov/electricity/annual/pdf/epa.pdf. [Accessed 3 April 2017].

Nevertheless, should we accept the premise that the economic value proposition associated with our use of fossil fuels will continue to be too attractive in the short term for society to wean itself from them, an approach to mitigating their environmental burden while enhancing their economic value proposition is to develop the technical means to cost-effectively use the cleanest fuel available (i.e., natural gas) in the most efficient and least environmentally burdensome manner possible. The state-of-the-art natural gas-to-electricity conversion system is a large natural gas combined cycle plant with a gross conversion efficiency of approximately 60% on a lower heating value (LHV) basis.[11] However, in the United States, electric grid transmission and distribution (T&D) losses of 5% reduce the state-of-the-art net delivered efficiency to 57%.[12] Furthermore, the average LHV-basis efficiency of all the utility-scale fossil-fueled plants on the US electric grid was 36% in 2015, and hence, the fossil-fueled average net-delivered efficiency was 34%, if T&D losses are included.[13] The average efficiency with which our nation generates electricity from fossil fuels has increased dramatically since the 1880's, as illustrated in Figure 1. Its steady progression stalled between 1960 and 2000; however, it has recently accelerated as more efficient and cost-effective natural gas plants are displacing less efficient coal plants. The INTEGRATE program seeks to accelerate this trend by further increasing the efficiency and lowering the cost of the capital assets required to generate and deliver electricity to commercial and industrial end users.

[11] U.S. Energy Information Administration, " Distributed Generation and Combined Heat & Power System Characteristics and Costs in the Buildings Sector" February 2017. [Online]. Available: https://www.eia.gov/analysis/studies/buildings/distrigen/pdf/dg_chp.pdf

[12] U.S. Energy Information Administration, "How much electricity is lost in transmission and distribution in the United States?" 16 February 2017. [Online]. Available: https://www.eia.gov/tools/faqs/faq.php?id=105&t=3. [Accessed 5 April 2017].

[13] U.S. Energy Information Administration. (2017, March). *Monthly Energy Review (MER).* Retrieved April 3, 2017, from Energy Information Administration: https://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf

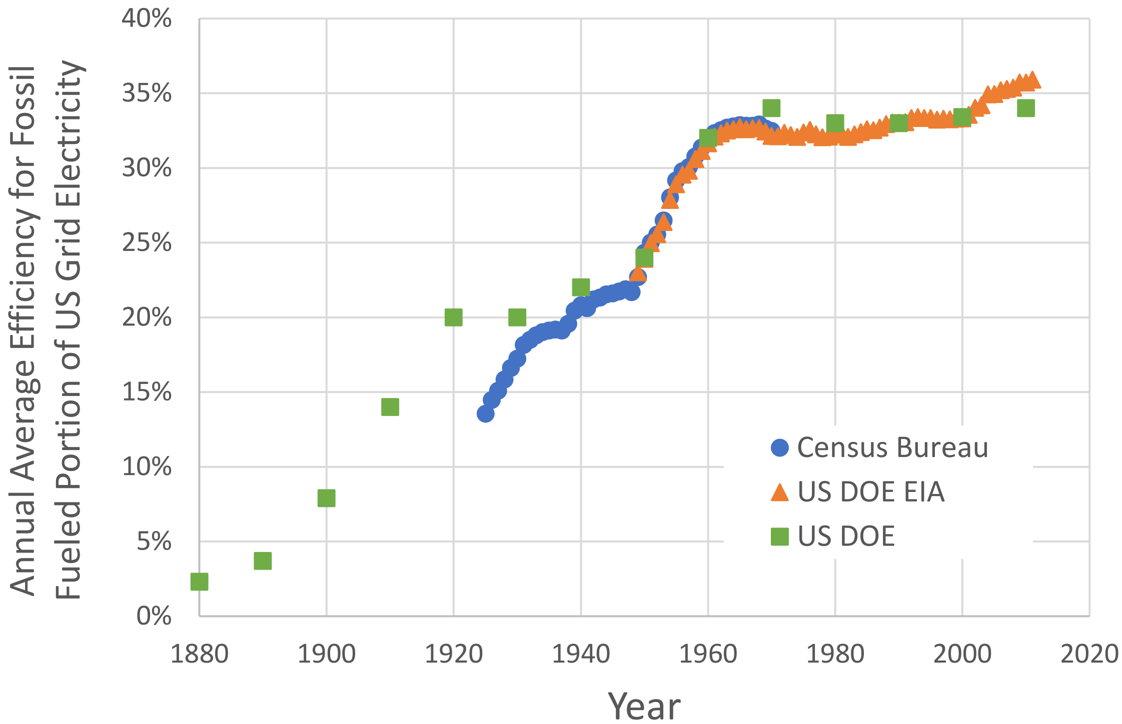


**Figure 1: Fossil fueled electric generation efficiency vs time.**[14,15,16]

The electric efficiency of a generator is only one driver of its overall economic value proposition. One more comprehensive metric that encompasses it and most of (e.g. with the exception of dispatchability) the major value drivers is the Levelized Cost of Electricity (LCOE). It is calculated using factors such as capital costs, operations and maintenance costs, fuel costs, electrical efficiency, capacity factor, and the discount rate. The LCOE for various state-of-the-art utility-scale electricity generators is shown in Figure 2. As can be seen in this figure, Advanced Combined Cycle plants are the third cheapest source of electricity at $80/MWh, behind geothermal and wind power, which have either limited geographical applicability or dispatchability limitations. These estimates suggest that the cost of utility-scale/centrally generated electricity varies between $50/MWh and $120/MWh, without consideration of the full maintenance and depreciation costs of the transmission and distribution system required to transmit their centrally generated electricity to the end users.

[14] US Census Bureau, Bicentennial Edition: Historical Statistics of the United States, Colonial Times to 1970, 1975.
[15] US Department of Energy, The Potential Benefits of Distributed Generation and Rate-Related Issues That May Impede Their Expansion, 2007.
[16] US Energy Information Administration, April 2017 Monthly Energy Review, 2017.

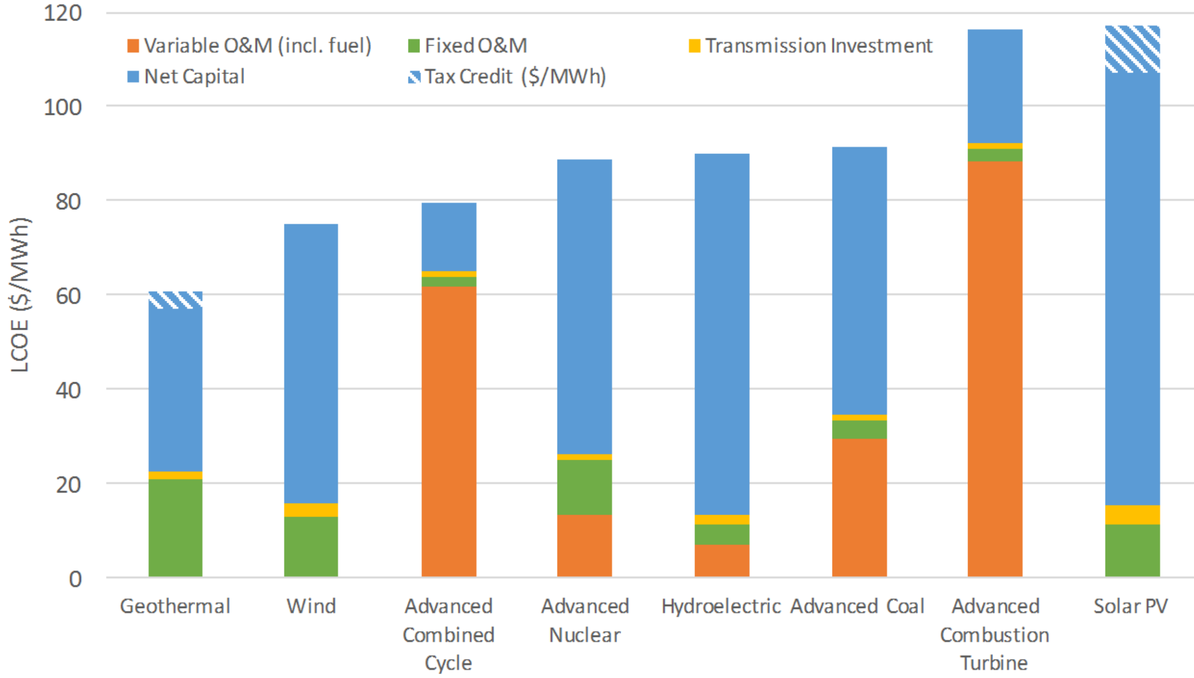


**Figure 2. Estimated LCOE through 2040 for various utility-scale generating technologies entering service in 2020.**[17]

Unfortunately, the cost of transporting electricity generated by the utility-scale central plants represented in Figure 2 to commercial, industrial, and residential end users substantially adds to the overall cost of electricity. This point is illustrated in Figure 3, where the estimated average costs of transporting both electricity and natural gas from their respective hubs (or "average natural gas hub price") to the three classes of end users in California and New England are provided[18]. In 2015, the average natural gas hub price was $10/MWh on an LHV basis. Per the simplified distribution system model in Figure 3, NG flowed from this hub to city gates, industrial sites, and nominally to the electricity hub. Estimated annual-average transportation costs are calculated as the differences between the NG prices at the three locations and the hub. NG that was worth $10/MWh at its hub was valued at $13/MWh at the electricity hub, where it was converted to electricity that had an average value of $40/MWh in California and New England in 2015.

This centrally-generated electricity was then transported to the commercial, industrial, and residential end users indicated in the figure at the costs indicated in yellow. Once again, these transmission and distribution costs were estimated from the difference between the annual

[17] EIA, Annual Energy Outlook 2015 (https://www.eia.gov/outlooks/aeo/pdf/0383(2015).pdf)

[18] These estimates were derived on an annual average basis using 2015 data from two datasets provided by the EIA: wholesale electricity and natural gas market data (https://www.eia.gov/electricity/wholesale/#history) and annual average end user prices (https://www.eia.gov/totalenergy/data/monthly/).

average end user prices and the annual average wholesale electricity market price. As can be seen in a comparison between the NG and electricity transmission and distribution costs that are highlighted in the bar chart in the bottom of the figure, these data suggest that it is substantially cheaper to transport natural gas than electricity. However, as a caveat, the natural gas costs must also account for the conversion efficiency[19] of the DG resources that are used to convert the NG to electricity for the end user. Nevertheless, the data presented in Figure 3 emphasize another element in the economic value proposition for ultra-high efficiency distributed generation systems: they can lower the overall cost associated with transporting energy to end users, while reducing the primary energy needed to satisfy their needs.

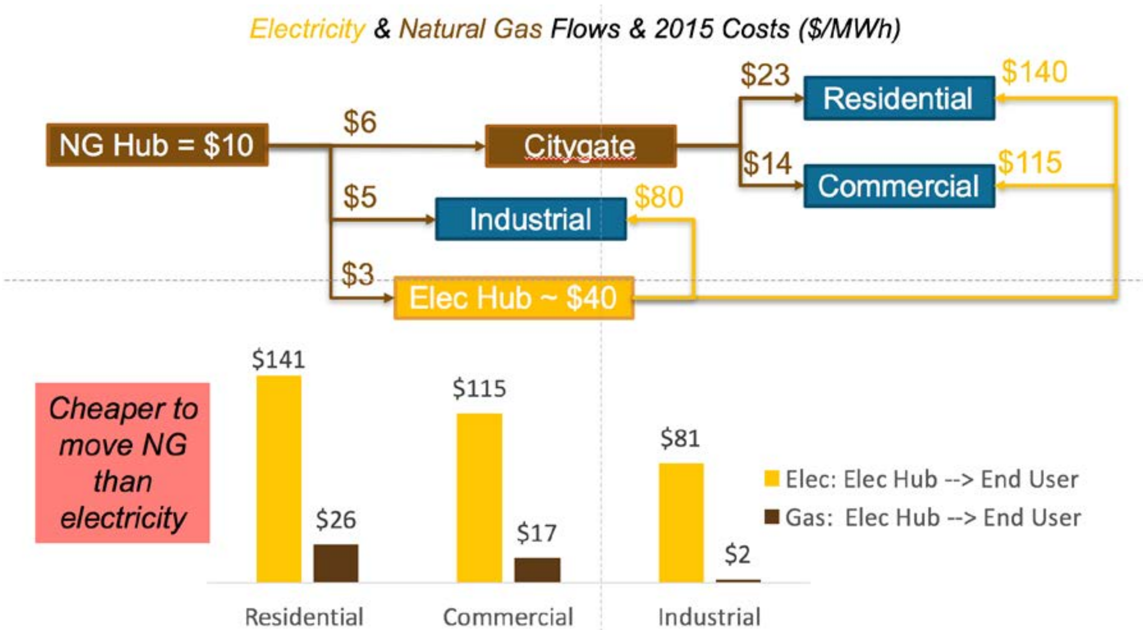


**Figure 3: Electricity and natural gas hub prices and effective transportation costs.**

In summary, the current US electrical system is dominated by central generation plants whose electricity must be distributed to end users via the electrical grid. The effective cost of transmitting and distributing that centrally generated electric power to end users can *exceed the cost of generation*. Ultra-high efficiency (>70%) distributed generation systems have the potential to lower the cost and environmental burdens associated with the provision of our electricity via:

1. A substantial reduction in the rate at which fuel is consumed and emissions are produced in the generation of our electric power from fossil fuels,
2. The avoidance of electricity transmission and distribution inefficiencies and costs,
3. The elimination of the requirement to use cooling water to achieve high fuel to electric efficiency, and

[19] Divide the cost by the LHV-basis fuel to electric power conversion efficiency

4. The potential to use waste heat from the electric generation process for on-site thermal needs.[20]

In the next section, a quantitative analysis of the end-user value proposition for DG will be described to establish INTEGRATE Program targets that could enable a 1 Quad/Year annual primary energy savings in the provision of the electricity required by commercial and industrial end-users. Such an energy savings would be worth $3B/year to the US economy at a $10/MWh cost of NG, without consideration of the benefits associated with reduced emissions, reduced water usage, and energy transmission and distribution costs.

### Requirements for Disruption

If the status quo is to be disrupted by a substantially more energy efficient and environmentally benign alternative, that alternative must provide a compelling economic value proposition for end users. DG systems can create economic value for such users by enabling them to avoid the purchase of grid-provided electricity by generating electricity onsite with generally less expensive natural gas. The attractiveness of this value proposition in a particular scenario is a function of the "spark spread" between natural gas and electric rates, the thermo-economic characteristics of the DG system, the capacity utilization of the DG equipment, and the potential to use waste heat from the electricity generation process to offset local thermal loads such as space or water heating.

The specific individual value proposition drivers and their relative importance in a nominal scenario are illustrated in the Internal Rate of Return (IRR) tornado chart that is shown in. In this scenario, a DG system with the targeted efficiency (70%), capital cost ($1800/kW), and maintenance cost ($0.02/kWh) was "operated" in a scenario in which the owner purchased natural gas at the 2015 US-average commercial price of $6.55/Mcf[21], and used the generated electricity to avoid the purchase of grid electricity that was valued at the 2015 US-average commercial price of $0.10/kWh. The electric capacity utilization of the system was 80% over the 20-year life of the hardware. Additionally, 50% of the waste heat produced by the system was assumed to be available to offset thermal loads previously satisfied by natural gas at an average baseline efficiency of 90%. However, only 25% of the available thermal capacity was assumed to be productively used. Lastly, the energy and maintenance rates were assumed to inflate at a 2% annual rate.

For the nominal assumptions, represented in the column to the right of the figure, the IRR for the investment in the DG system was 21%, and the simple payback period for the initial capital investment was 5.1 years. Both values are represented in the nominal economics table to the lower left of Figure 4. In the actual tornado chart, each of the 10 assumed parameters was

[20] However, while the use of waste heat for thermal needs would enhance the effective electric efficiency of the DG system, at the high electrical efficiencies targeted in this program, capture of this heat in an economically attractive manner is likely to be a challenging proposition of second order importance. Consequently, it will not be emphasized in this program.
[21] Mcf = thousand cubic feet

individually varied ±10% and the differences between the updated IRR and nominal IRR (i.e. the ΔIRR) are plotted in the figure.

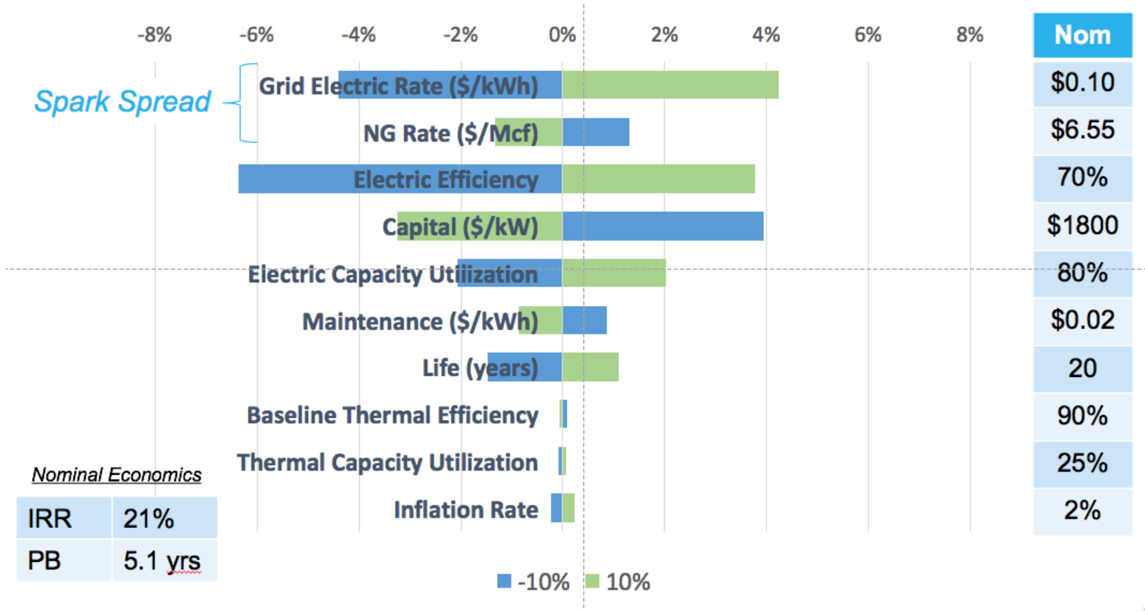


Figure 4: DG value proposition (IRR) driver tornado chart

As can be seen in Figure 4, the prevailing electric and natural gas rates are significant drivers, with the grid electric rate being more important. Furthermore, from a system design perspective, the two most important system characteristics are the electric efficiency and the capital cost. Electric capacity utilization, life and maintenance costs are the next most important drivers. Lastly, of the ten-metrics used in the analysis represented in the figure, the baseline thermal efficiency and thermal capacity utilization were the least significant. This result illustrates the relative unimportance of the thermal output of the system at the targeted 70% electric efficiency. Hence, in practice, it may be challenging to economically justify the utilization of the waste heat produced by such an efficient device. Consequently, the design and implementation of a waste heat recovery system on the envisioned DG system is not emphasized in this FOA unless the waste heat is used within the system.

The widespread commercial viability of the envisioned hybrid DG system technology is essential for them to enable a 1 Quad/year primary energy savings. Thus, in order to estimate the viability of such systems, a simple market model was developed to predict the maximum achievable market penetration (MMP) of the technology as a function of the economic value that a system could provide to its owners. This model is similar to those utilized in the National Renewable Energy Lab's (NREL's) dGen model[22] but has a simple functional form:

[22] Sigrin, B., Gleason, M., Preus, R., Baring-Gould, I., & Margolis, R. (2016). *The Distributed Generation Market Demand Module (dGen): Documentation.* National Renewable Energy Lab (NREL).

$$MMP = \frac{A}{\sigma\sqrt{2\pi}} exp\left(-\frac{1}{2}\left(\frac{PB}{\sigma Life}\right)^2\right)$$

*A=0.3193, σ=0.1274*.

A and σ were calculated in an optimization that was performed to minimize the sum of the squared differences between the resulting market curve and three assumed target market penetrations at payback periods of 0 (100%), 3 (50%), and 10 (0%) years. *PB* and *Life* are the simple payback period and system life in consistent units (e.g. years). The resulting MMP vs PB curve is shown in Figure 5.

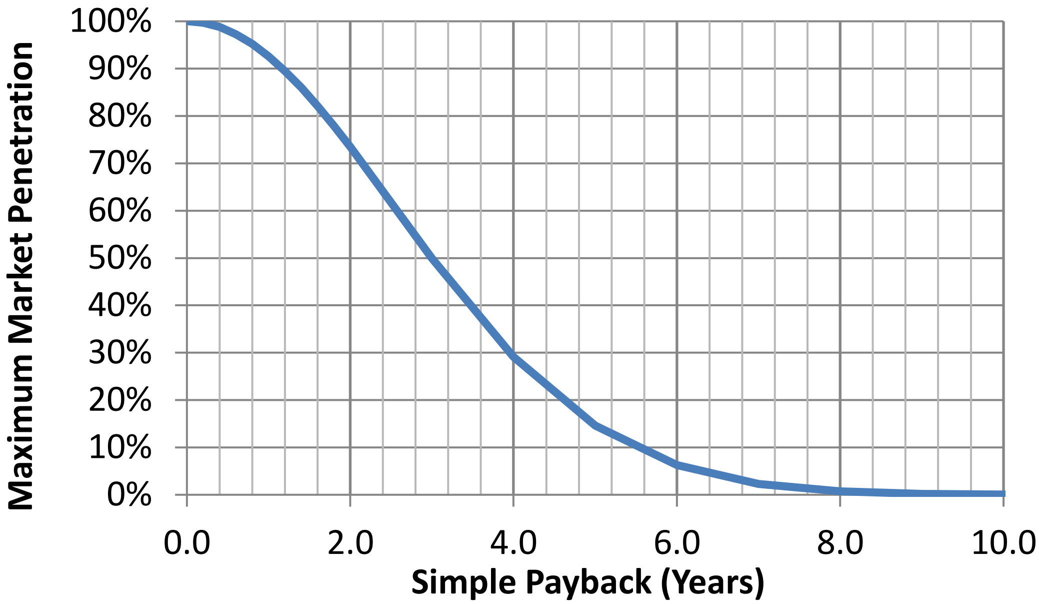


**Figure 5: Assumed maximum market penetration versus simple payback for a system with a 20-year life.**

Using the curve in the state-level market data and DG system characteristics delineated in Table 1, the total US commercial market penetration was calculated as a function of the electric efficiency and installed price. This market penetration and the system effective electric efficiencies were then used to estimate the potential nationwide primary energy savings associated with the envisioned hybrid systems technology. Contours of the resulting estimated annual primary energy savings in Quads are shown in Figure 6. In the calculation of this energy savings, it has been assumed that the installed DG systems would displace electricity that would have been produced by a fossil fueled plant operating at the net-delivered US average of 34%[23]. In Figure 6, the 1 Quad/year contour is highlighted with white a dashed line. Also, the electric efficiencies and installed costs of a number of commercial Combined Heat and Power (CHP)

[23] This simplifying assumption was made in lieu of a comprehensive multi-year state-by-state micro-economic analysis to determine which specific generation alternatives would be displaced by the envisioned hybrid systems technology.

systems are indicated on the figure for comparative purposes[24]. A technology gap—an ARPA-E opportunity—in the lower right (most attractive) portion of the chart is evident.

**Table 1: Assumed parameters for market penetration and impact study**

| Parameter | Assumed Value |
|---|---|
| **Grid Electric Rate ($/kWh)** | 2015 US State Commercial Averages |
| **Natural Gas Rate ($/kWh)** | 2015 US State Commercial Averages |
| **Electric Grid Efficiency** | 34% (US Fossil Fueled Average) |
| **State Energy Usage** | 2015 US State Totals |
| **Electric Efficiency** | Variable: $20\% < \eta_{elec} < 80\%$ |
| **Installed Price ($/W)** | Variable: 0.2 < P < 12 |
| **Thermal Efficiency** | Variable: $(1 - \eta_{elec}) / 2$ |
| **Maintenance Cost ($/kWh)** | $0.02 |
| **Electric Capacity Utilization** | 85% |
| **Thermal Capacity Utilization** | 25% |
| **Baseline Thermal Efficiency** | 90% |
| **System Life (years)** | 20 |

[24] U.S. EPA, Catalog of CHP Technologies, March 2015, https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf.

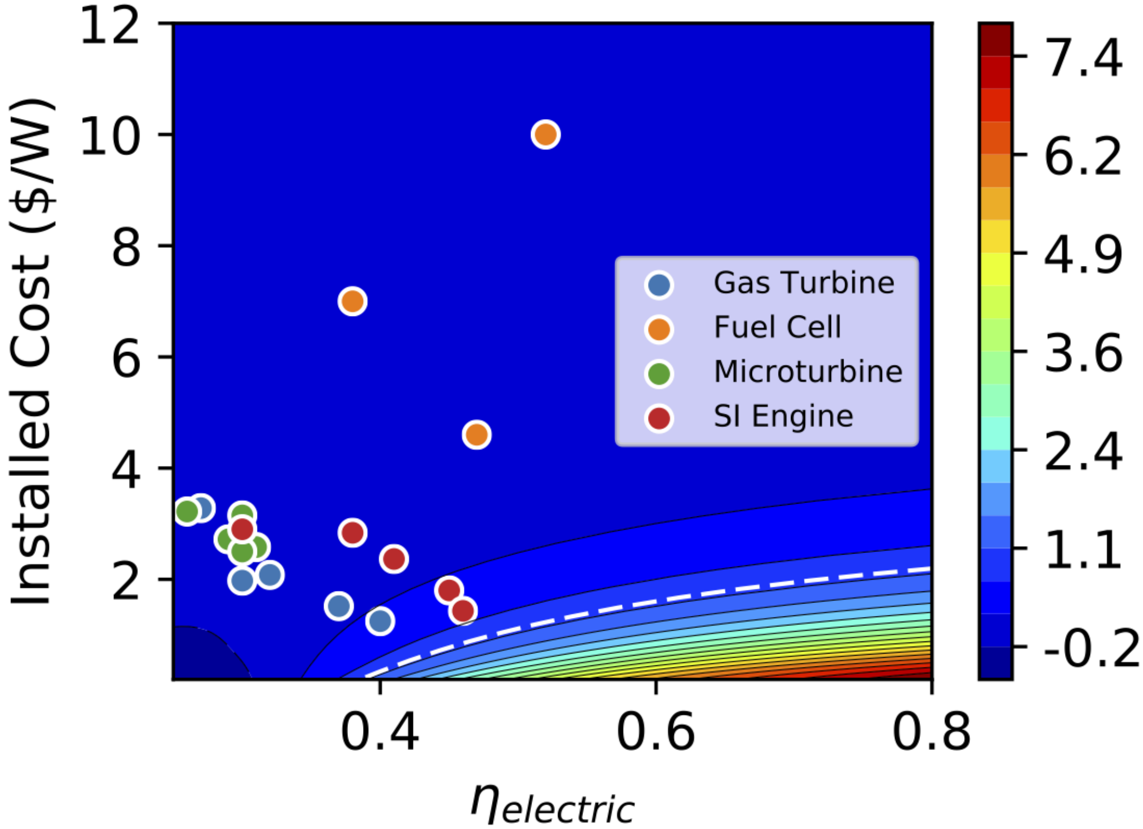


**Figure 6: Estimated annual commercial primary energy savings (Quadrillion BTUs) contours drawn as functions of the installed price and electric efficiency. The energy savings contour color legend is shown to the right of the plot (in units of quads of energy saved per year).**

## C. Program Objectives

The objective of the INTEGRATE program is to reduce the cost and increase the energy efficiency associated with the provision of electric power to commercial and industrial customers. The program seeks to accomplish this objective by encouraging the development of hybrid system designs and supporting component technologies that would enable the realization of highly efficient (≥70%) and low cost (<$1.8/W installed) DG systems at commercial scale (100 kW or greater). The analysis presented in the prior section suggests that a system with the abovementioned characteristics would have the potential to achieve the wide-spread commercial adoption required for them to provide >1 Quad/year and >$3B/year of nationwide primary energy savings[25].

[25] The nationwide commercial electric market penetration required to enable the targeted energy savings at an electric efficiency of 70% is 25%.

## D. Approach

In the pursuit of the abovementioned efficiency and cost targets, this program seeks to leverage the thermo-economic synergies offered by hybrid fuel cell and heat or reactive engine electric generation systems. These devices have the greatest known fuel to electric power conversion efficiency potential through their combined use of a fuel cell and a waste-exergy conversion device (e.g. gas turbine, internal combustion engine, Stirling engine). Additionally, from a power-specific cost (e.g. $/W) perspective, the use of a typically lower-cost engine to generate a portion (e.g. 10-20%) of the electric power helps to reduce the overall power-specific cost by amortizing the cost of the more expensive fuel cell over a larger output. Furthermore, additional cost benefits versus traditional fuel cells can be realized if the engine can be made to perform a portion of services that are typically satisfied by the fuel cell BOP.

For illustrative purposes, a simplified schematic of a notional fuel cell/recuperated gas turbine hybrid system is shown in Figure 7. In this notional system, the gas turbine compressor and recuperator feed and condition (i.e. pressurize and heat) the cathode stream air before it is fed into the stack. Natural gas fuel and (recovered) water are fed into the anode side of the stack, where the fuel is steam-reformed using waste heat from the electrochemical conversion process. The anode and cathode streams exiting the stack carrying waste exergy in the form of heat and unreacted fuel are fed into the gas turbine combustor where the remaining fuel is combusted before the products are expanded through the turbine to generate shaft work—to drive the compressor and to supplement the stack electrical output via the generator.

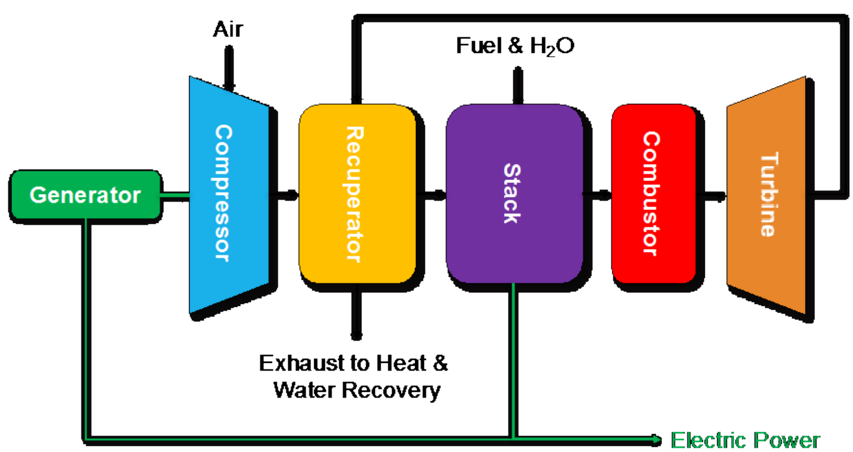


**Figure 7: Simplified illustration of a hybrid system configuration example**

In the remainder of this section, the efficiency and cost synergies offered by hybrid systems are described in more detail with the hope of motivating interest in the technology and incubating new enabling concepts and technologies. The discussion is divided into two sub-sections: Efficiency Synergies & Cost Synergies.

### Efficiency Synergies

Previous studies have shown that fuel cell and engine hybrid systems have the potential to achieve LHV-basis fuel-to-electricity conversion efficiencies in excess of 70%.[26,27,28,29,30] This point is illustrated on an idealized basis in Figure 8, where the ideal LHV-basis efficiency[31] of a fuel cell stack operating on hydrogen fuel is plotted versus the stack temperature (blue line). As can be seen in the figure, the ideal stack efficiency decreases with temperature. Additionally, the efficiency of a Carnot heat engine with a low-side temperature of 25 °C is plotted versus its high-side temperature (green curve), and, as can be seen in the figure, its efficiency increases with high-side temperature. If we construct a hypothetical hybrid system with an ideal fuel cell topping cycle and a Carnot engine bottoming cycle that converts a portion the waste exergy from the fuel cell into useful work, and if we furthermore assume the stack temperature is also the high-side temperature of the Carnot bottoming cycle, the LHV-basis efficiency of this idealized hybrid system is an approximately constant 94% with temperature, as seen in Figure 8 (red line).

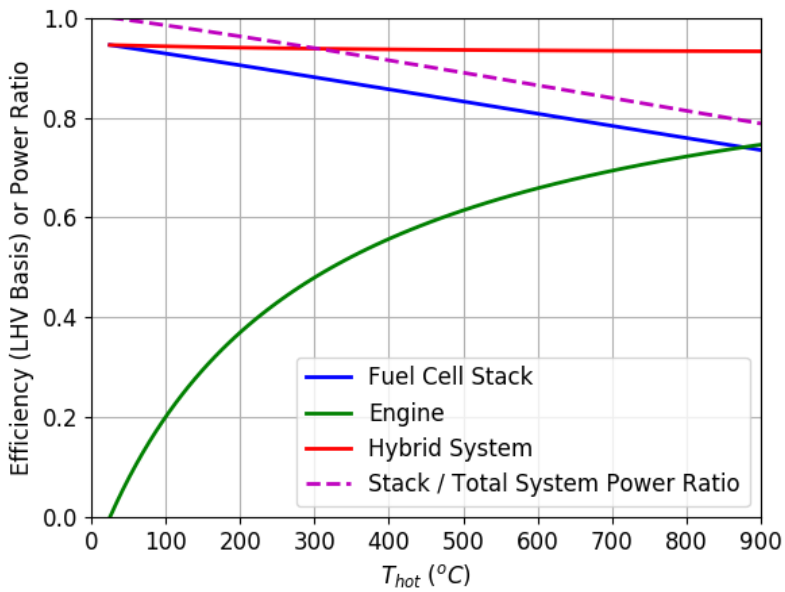


**Figure 8: Ideal efficiency comparisons between fuel cells, gas turbines and hybrid systems**

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[26] Fyffe, J.R., et al. "Mixed combustion–electrochemical energy conversion for high-efficiency, transportation-scale engines." International Journal of Engine Research (2016): 1468087416665936.
[27] Kobayashi, Y., et al. "Extremely high-efficiency thermal power system-solid oxide fuel cell (SOFC) triple combined-cycle system." Mitsubishi Heavy Industries Technical Review 48.3 (2011): 9-15.
[28] McLarty, D. et al. "Fuel cell–gas turbine hybrid system design part I: Steady state performance." Journal of Power Sources 257 (2014): 412-420.
[29] Brouwer, Jack. "Hybrid gas turbine fuel cell systems." (2006).
[30] K. Miyamoto, M. Mihara, H. Oozawa, K. Hiwatashi, K. Tomida, M. Nishiura, H. Kishizawa, R.Mori, Y. Kobayashi. "Recent progress of SOFC combined cycle system with segmented-in series tubular type cell stack at MHPS." ECS Transactions. 68 (2015) 51-58.
[31] The ideal efficiency plotted is the ratio of the Gibbs Heat of Reaction to the Enthalpy of Reaction for a stoichiometric mixture of hydrogen and oxygen.

Unfortunately, in the real world, unavoidable non-idealities (e.g. stack overpotentials, combustion exergy destruction, heat transfer across finite temperature differences, viscous losses) result in an achievable efficiency that is appreciably less than the ideal represented in Figure 8. Hence, the program goal of 70% was established as a balance between the ambitious targets required for the targeted primary energy savings and the non-idealities of real-world operations.

A specific example of how this efficiency target might be achieved in practice is provided in Figure 9, where an ideal gas/constant composition cycle model was used to estimate the LHV-basis efficiency and specific work of a number of different fuel cell/microturbine hybrid cycle options. In Figure 9, two cycle parameters were varied—the fuel cell to total work ratio and the turbine inlet temperature, while the other parameters in the cycle model were assumed constant. A synopsis of these parameters is provided in Table 2. In Figure 9, the fraction of system work provided by the stack increases from 0 (a "pure" microturbine) on the lower solid curve to 0.8 on the upper solid curve, and turbine inlet temperature increases from 850 °C on the leftmost dotted curve to 1250 °C on the rightmost dotted curve. The current state of the art commercial microturbine (i.e. "Baseline" in Table 2) is approximately represented by the lower left most point, and the best test case evaluated is the upper right most point (i.e. "Best" in Table 2).

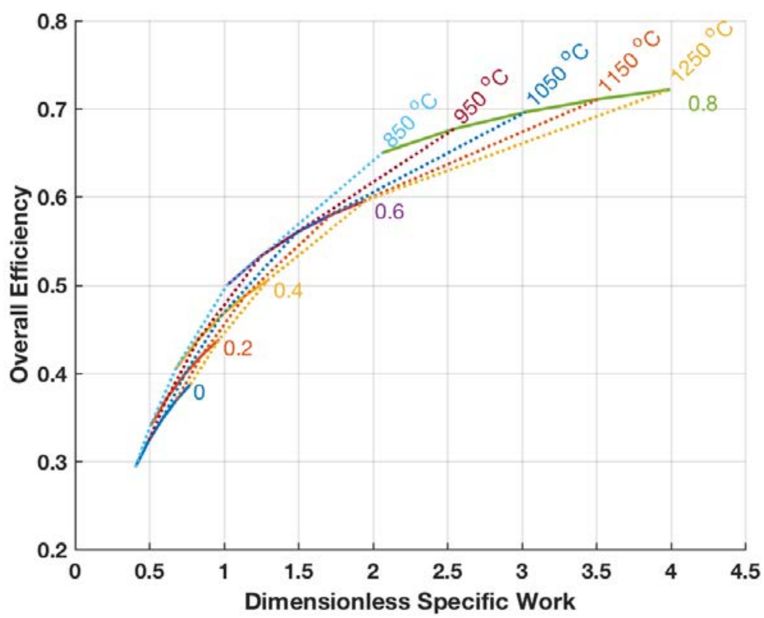


**Figure 9: Hybrid system efficiency and specific work map for the fuel cell and recuperated gas turbine system pictured in Figure 7. Two parameters were varied to draw the map--the fuel cell stack to total work ratio and the turbine inlet temperature. The stack to total work ratio is constant along the solid lines, and the turbine inlet temperature is constant along dotted lines. A microturbine-only system is represented by the stack to power ratio of 0 line, with the baseline system being the lowest and leftmost point.**

**Table 2: Assumed variable (Stack /Total Work Ratio and Turbine Inlet Temperature) and constant parameters used to generate the performance map presented in Figure 9 and the resulting performance metrics.**

| Input Parameter | Baseline | Best |
|---|---|---|
| Stack / Total Work Ratio | 0 | 0.8 |
| Turbine Inlet Temperature (°C) | 850 | 1250 |
| Working Fluid | Air | |
| Combined Generator & Inverter Efficiency | 95% | |
| Fuel LHV (MJ/kg) | 50 | |
| Inlet Pressure Ratio (Inlet PR) | 0.98 | |
| Compressor Polytropic Efficiency | 85% | |
| Compressor PR | 4 | |
| Recuperator Effectiveness | 0.8 | |
| Hot Recuperator PR / Cold Recuperator PR | 0.95 / 0.98 | |
| Combustion Efficiency / PR | 99% / 0.97 | |
| Turbine Isentropic Efficiency | 85% | |
| Bearing Loss / Turbine Gross Power | 2% | |
| **Calculated Performance Metric** | **Baseline** | **Best** |
| Overall LHV to AC Power Efficiency | 29% | 72% |
| Power / Inflow Enthalpy Flux of Air into System | 0.4 | 4.0 |

As suggested by the data and assumptions presented in Figure 9 and Table 2, respectively, fuel cell and recuperated microturbine efficiencies in excess of 70% are attainable for achievable component efficiency performance levels—if the cycle can be modified to accommodate higher turbine inlet (and other hot section) cycle temperatures and the addition of a fuel cell stack without negatively impacting the cycle through increased “combustor-section” pressure drop or thermal losses. However, recognizing that in practice it will be difficult to avoid these two penalties in their entirety, it is hoped that the performances of other components (e.g. compressors, turbines, heat exchangers) in the cycle can be enhanced to counteract any negative cycle performance implications associated with the introduction of a stack.

**Lastly, while a direct[32] fuel cell/gas turbine hybrid system has been used as a nominal design for illustrative purposes, it is recognized that alternate hybrid system configurations, including indirect[33] cycles and alternative engine (e.g. internal combustion, Stirling, etc.) cycles, may be more attractive from an efficiency (and/or cost) perspective. Regardless of the system design, applicants are expected to provide sufficient detail (i.e., greater than or similar to the specificity of the nominal design in this FOA) regarding the technical and commercial feasibility of their designs.**

[32] The fuel and engine share the same working fluid.
[33] The fuel cell and engine exchange only heat and do not share the same working fluid.

### Cost Synergies

In addition to the above-mentioned efficiency synergies, hybrid systems offer the potential for substantial cost synergies as well. These synergies arise through the

1. the generation of a portion (nominally 10-20%) of the system's power with a cheaper source (the engine) that converts stack waste exergy to additional electric power,
2. the potential use of the engine to increase the areal specific power density (e.g. W/cm$^2$) of the stack via pressurization and thereby lower its power specific cost (e.g. $/W), and
3. the use of the engine to serve as at least a portion of the fuel cell BOP.

Unfortunately, fuel cells are currently very expensive systems relative to the energy cost savings that they enable for their end users in many US states, as is implicitly suggested by the aggregate data presented in Figure 6. Furthermore, as can be seen in Figure 6, per the EPA CHP Catalog, the current installed costs of the most efficient technology (SOFC-based systems with $\eta$=52%) and arguably the best candidate for hybrid systems is $10/W versus the FOA target of $1.8/W.

In the interest of enabling the identification of potential paths from the current State-of-the-Art (SOA) to the FOA target while simplifying the working cost metric, the installed costs referenced above are converted to equipment manufacturing costs in Table 3. As can be seen in the table, the ultimate high-volume learned-out equipment manufacturing cost target for the FOA is $0.9/W versus a current estimated cost of $6/W.

**Table 3: Installed cost to customer drivers—estimated current SOA and ultimate hybrid system targets. All costs in $/W. In the "Current SOA" scenario, publically available information was used for the installed cost equipment price[34], and a gross margin of 25% was assumed to yield an estimate for the equipment cost given an equipment price. In the "Hybrid Targets" scenario, the installed cost to the customer of $1.8/W was calculated from a market model—given a system with a 70% electric efficiency and a desire for a 1 Quad/year fuel energy savings for commercial users. In order to back out an equipment cost target, the installation cost was assumed to be one-third of the total cost to the customer, and the ultimate equipment gross margin was assumed to be 25%.**

| | *Current SOA* | *Hybrid Targets* |
|---|---|---|
| Installed Cost to Customer | $10 | $1.8 |
| Installation Cost | $2 | $0.6 |
| Equipment Price | $8 | $1.2 |
| Equipment Gross Margin | $2 | $0.3 |
| Equipment Cost | $6 | $0.9 |

While the $6/W Current SOA equipment cost was calculated (top-down) from a $10/W final installed cost starting point and two additional assumptions regarding installation costs and

[34] https://www.greentechmedia.com/articles/read/bloom-update

equipment margin, the same \$6/W Current SOA equipment cost may be estimated (bottom-up) from a series of assumptions regarding the manufacturing costs of the stack and BOP. These assumptions are provided in Table 4. Specifically, if the areal specific cost of a stack is assumed to be \$0.56/cm$^2$, and the stack is operated at a power density of 250 mW/cm$^2$, the power specific cost of the stack would be \$2.2/W of stack gross power. Furthermore, if the stack was one-half the cost of the system, the cost of the entire system would be \$4.4/W of stack gross power. If the BOP (inclusive of the stack DC to output AC power conversion losses) consumes 25% of the stack gross power, the resulting net power-specific cost of the system is ~\$6/W. Lastly, if the combined efficiency of the natural gas fuel processor/steam reformer and the stack are 70%, the net efficiency of the system would be 53%--inclusive of the abovementioned parasitic losses.

**Table 4: Assumptions used to establish a bottom-up estimate of the SOA manufacturing cost of a "pure" fuel system**

| Parameter | Assumed value |
|---|---|
| Stack Cost (\$/cm$^2$) | 0.56 |
| Power Density (mW/cm$^2$) | 250 |
| BOP / Stack Cost Ratio | 1 |
| BOP / Stack Power Ratio | 0.25 |
| Stack * Fuel Processor Efficiency | 70% |

Given this baseline, the next points to be addressed are the specific cost and performance synergies associated with fuel cell and engine hybrid systems and the required magnitudes of these synergies to realize the system manufacturing cost target of \$0.9/W. In Figure 10, for illustrative purposes, a potential path to the manufacturing cost target is provided that leverages hybrid system synergies, stack power-specific manufacturing cost advances, and engine manufacturing cost and performance advances. This path was conceived using the example system provided in Figure 7 as the notional hybrid system. However, it is important to note that the inclusion of this pathway in this FOA is ***only intended to provide an example*** of how the cost target might be met. It is ***not*** meant to be prescriptive and potential applicants are encouraged to deviate from it if they identify alternative pathways that are feasible and compelling to meet the targets of the FOA.

In Figure 10, from the "Current SOA" baseline on the left of the figure, a series of enhancements to the system and associated manufacturing processes are modeled and the resulting impact on the cost and performance of the system are indicated. A summary of these changes is provided in Table 5. Applicants are encouraged to consult one of the DOE-supported cost studies for guidance on the anticipated relative contributions of the various components to the overall cost of a "pure" fuel cell system.[35,36,37]

Innovative technology concepts that either enable one or more of the identified changes or identify and enable new ones are of interest to ARPA-E in the INTEGRATE program.

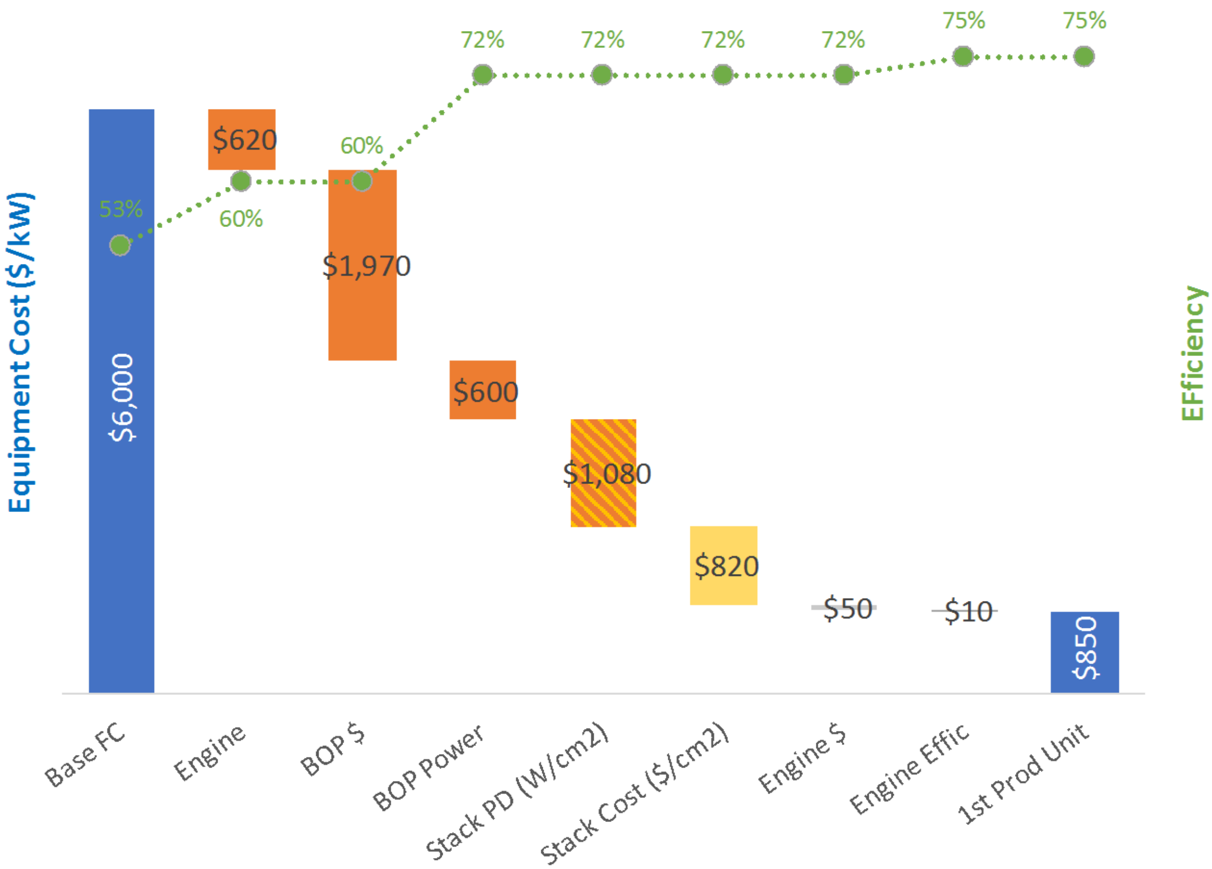


**Figure 10: Notional path from the estimated Current SOA to the FOA manufacturing cost target via the leveraging of hybrid system synergies (orange bars and orange/yellow striped bar), stack power specific cost advances (orange/yellow striped bar and yellow bar), and engine manufacturing cost and performance advances (gray bars).**

[35] Scataglini, R., et al, "A Total Cost of Ownership Model for Solid Oxide Fuel Cells in Combined Heat and Power and Power-Only Applications", Lawrence Berkeley National Laboratory. 2015.
[36] Battelle Memorial Institute, "Manufacturing Cost Analysis of 100 and 250 kW Fuel Cell Systems for Primary Power and Combined Heat and Power Applications", 2016.
[37] Weimar, MR, et al, "Cost Study for Manufacturing Solid Oxide Fuel Cell Power Systems", Pacific Northwest National Lab, 2013.

**Table 5: System changes behind power-specific cost reductions and efficiency improvements in the example path to the cost target provided in Figure 10.**

| Bar | Change |
|---|---|
| **Engine** | An engine with an efficiency of 30% and a power-specific cost of $1/W that generates power with the waste exergy produced by the stack is added to the system. |
| **BOP $** | The abovementioned engine is used to provide many of the functions of the BOP in a traditional "pure" fuel cell system. The resulting economies of scope (e.g. component removal) enables a 75% reduction in the cost of the BOP. |
| **BOP Power** | In addition to the abovementioned cost savings, the engine enables a reduction in the parasitic power draw of the BOP by providing some of the services. (E.g. The compressor in the system shown in Figure 6 replaces the air blower typically used to supply the stack.) These economies of scope enable a 75% reduction in the parasitic power draw of the BOP. |
| **Stack Power Density ($W/cm^2$)** | Through a combination of hybrid system synergies (e.g. stack pressurization, internal reforming) and/or stack technology advancements that lower the ASR, the areal power density of the stack at a fixed voltage is doubled—from 250 $W/cm^2$ to 500 $W/cm^2$. |
| **Stack Cost ($\$/cm^2$)** | A combination of stack materials changes, weight reductions, and/or manufacturing process advancements enables a 75% reduction in the areal-specific cost of the stack. |
| **Engine $ Cost ($/W)** | The cost of the engine is reduced by 50%--from $1/W to $0.5/W. (However, as the engine is only providing ~10% of the system power, a significant reduction in the cost of the engine has a modest impact on the overall cost of the hybrid system.) |
| **Engine Efficiency** | The efficiency of the engine bottoming cycle is increased from 30% to 40%. (A corollary of the above parenthetical comment applies here too.) |

## E. PROGRAM STRUCTURE

ARPA-E anticipates a two-phase INTEGRATE program with the first phase (I) focused on the development of enabling component and sub-system technologies and the second phase (II) focused on the development and validation of the complete integrated system technology.

Applicants may provide budgets and task descriptions that cover either

1) only Phase I, or
2) both Phase I and Phase II.

However, Phase II would only be awarded upon the successful completion of Phase I and will be subject to the availability of appropriated funds. ARPA-E support for individual Phase I projects will be limited to $4M, and ARPA-E support for combined Phase I and Phase II projects will be limited to a total of $12M.

For both Phase I and combined Phase I and II submissions, applicants must submit hybrid system designs for 100 kW-scale systems; these designs must include a detailed explanation of how the performance targets, outlined below, will be achieved. Additionally, applicants must identify any critical enabling technologies required to enable the achievement of the targets, and they must propose to develop at least a subset of the identified technologies in a Phase I effort.

It is anticipated that critical enabling technologies that will be supported in this FOA will include but are not limited to--

- advanced integrated engine/BOP concepts,
- advanced fuel cell stack concepts and/or manufacturing approaches,
- advanced BOP components (e.g. high temperature heat exchangers), and
- advanced control system technologies.

However, as the ultimate program goal is the demonstration of the viability of ultra-high efficiency distributed generation systems within four years, submissions limited to the topic areas listed below are specifically not of interest—

- “paper” studies of multiple system concepts,
- new material discovery efforts, or
- “large-scale” system demonstrations of existing component technologies.

Nevertheless, it is recognized that the abovementioned activities may be included as subtasks in submissions to this FOA in order mitigate or reduce risk, as appropriate.

## F. TECHNICAL PERFORMANCE TARGETS

The INTEGRATE FOA intends to advance the commercial and technical feasibility of ultra-high efficiency commercial-DG-scale (>100 kW) hybrid systems. As discussed above, in order to achieve the targeted nationwide annual fuel savings, aggressive efficiency (>70%) and equipment cost (<$0.9/W) targets have been established.

However, while the attainment of the aforementioned metrics is believed to be essential to wide-spread commercial adoption of the technology, it is not sufficient. The resulting hybrid system must also have the durability, reliability and lifespan required to enable an attractive economic value proposition. For purposes of this FOA, these three desirable system characteristics are quantitatively expressed as an energy-specific maintenance cost target of ≤$0.02/kWh, a system availability of ≥95%, and a system lifetime target of ≥20 years. The complete list of system performance targets is summarized in Table 6.

**Table 6: Hybrid system thermo-economic system performance metrics**

| ID | Parameter | Value |
|---|---|---|
| **1.1** | Net System AC Power | ≥ 100 kW |
| **1.2** | Fuel | Natural Gas |
| **1.3** | Net Fuel LHV to AC Electric Power Conversion Efficiency | ≥ 70% |
| **1.4** | Full Production Equipment Manufacturing Cost | ≤ $0.9/W |
| **1.5** | System Maintenance Cost | ≤ $0.02/kWh |
| **1.6** | System availability | ≥95% |
| **1.7** | System Life | ≥ 20 years |

Submissions to the INTEGRATE FOA must include the following--

1. A specific system concept with an estimate of the overall 100 kW-scale electric efficiency and the manufacturing cost;
2. Specification of the critical enabling technologies/components that will be developed in Phase I and Phase II, if applicable.;
3. Specification of the projected performances and costs of the proposed individual technologies/component(s);
4. Identification of the major performance, cost, and/or durability risks to the widespread commercial realization of the proposed system concept;
5. An associated plan to reduce the identified risks[38];
6. Specific identification of the individual risks that are proposed to be addressed during Phase I[39];
7. A list of proposed success criteria for the efforts that are proposed for each risk that would be reduced under the INTEGRATE program; and
8. Specific justification for why the proposed success criteria are supportive of the overall system efficiency, cost, and/or maintenance goals identified above in Table 6.

# II. <u>Award Information</u>

## A. <u>Award Overview</u>

ARPA-E expects to make approximately $20 million available for new Phase I (as described below) awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 5-15 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

[38] While the ultimate goal of the FOA is the development of >100 kW-scale DG systems, applicants are encouraged to pursue risk-reduction activities that are of appropriate scale for the risk to be reduced. (I.e. It is expected that sub-scale component, sub-system or system demonstrations may be proposed.)

[39] It is not necessary to address all the identified risks during Phase I. However, applicants are encouraged to propose the reduction of the most significant risk(s) identified.

ARPA-E anticipates a 2-phase, 4-year INTEGRATE Program. The period of performance for Phase I may not exceed 24 months. Phase II, also a maximum of 2 years, may only be awarded contingent upon successful completion of Phase I and will be subject to the availability of appropriated funds. ARPA-E expects the start date for funding agreements to be June 2018, or as negotiated.

Individual awards for Phase I may vary between $250,000 and $4 million.

Individual awards for Phase I and Phase II (if a Phase I project is chosen to progress to Phase II) combined may vary between $250,000 and $12 million.

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

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

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

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

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

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

## B. 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."[40] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.C below.

### 1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[41]

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.

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

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

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

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

[41] The Prime Recipient is the signatory to the funding agreement with ARPA-E.

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

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

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

### 3. 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.

## C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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

- Project Teams must adhere to ARPA-E's agency-specific and programmatic requirements.

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

# III. Eligibility Information

## A. Eligible Applicants

### 1. Individuals

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[42] as the lead for a Project Team,[43] or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

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

[43] 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.

### 2. Domestic Entities

For-profit entities, educational institutions, and nonprofits[44] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

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

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

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

### 3. Foreign Entities

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. Foreign entities must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed or to be formed) under the laws of a State or territory of the United States to receive funding. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate. The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/. 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

[44]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.

internal governance structure and its internal rules to the Contracting Officer (ARPA-E-CO@hq.doe.gov).

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

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;
- Provisions for members' cost sharing contributions; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

## B. COST SHARING[45]

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 Cost[46] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[47]

### 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).

[45] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[46] 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.
[47] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

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

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80%, 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.[49]

- 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%, 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.

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

[49] See the information provided in previous footnote.

- 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 period of performance, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

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

### 5. Cost Share Allocation

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

### 6. Cost Share Types and Allowability

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

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

In addition, Project Teams may not use independent research and development (IR&D) funds[50] to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment Agreements.

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

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

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

### 7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

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

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

### 8. COST SHARE VERIFICATION

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

## C. OTHER

### 1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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

Full Applications are deemed compliant if:

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

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

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploads its response to ARPA-E eXCHANGE by the deadline stated in the FOA; and

- The Replies to Reviewer Comments comply with the content and form requirements of Section IV.E of the FOA.

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

### 2. Responsiveness Criteria

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

- Submissions that fall outside the technical parameters specified in this FOA.
- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).

- Submissions for proposed technologies that are not transformational, as described in Section I.A of the FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress.
- Submissions that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.
- Submissions that describe a technology but do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

### 3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

Submissions that are limited to the topic areas listed below may be deemed nonresponsive and may not be merit reviewed or considered:

- "paper" studies of multiple system concepts,
- new material discovery efforts,
- systems powered by fuels other than natural gas,
- systems requiring an operational input that is not easily distributed via existing infrastructure, or
- systems not incorporating a fuel cell as one of the sub-systems.

### 4. LIMITATION ON NUMBER OF SUBMISSIONS

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

# IV. APPLICATION AND SUBMISSION INFORMATION

## A. APPLICATION PROCESS OVERVIEW

### 1. REGISTRATION IN ARPA-E eXCHANGE

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

### 2. CONCEPT PAPERS

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

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

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

### 3. FULL APPLICATIONS

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

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

### 4. Reply to Reviewer Comments

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

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

### 5. Pre-Selection Clarifications and "Down-Select" Process

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

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

### 6. Selection for Award Negotiations

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

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

### 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 and Budget Justification Workbook/SF-424A. A sample Summary Slide is available on ARPA-E eXCHANGE. Applicants may use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the template for the Summary Slide, the template for the Summary for Public Release, the template for the Reply to Reviewer Comments, and the template for the Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures Form is available on ARPA-E eXCHANGE.

## C. Content and Form of Concept Papers

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

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

- The first paragraph must include the Lead Organization's Name and Location, Principal Investigator's Name, Application Type (Phase I or Phase I & II), and Project Duration. Proposed Funding (Federal and Cost Share) is optional.

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

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

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

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

### 1. Concept Paper

#### a. Concept Summary

- Describe the proposed concept with minimal jargon, and explain how it addresses the Program Objectives of the FOA.
    - o Describe and illustrate via a flow diagram the ultimate ≥100 kW hybrid system concept
    - o Provide projections for the LHV-basis natural gas to electric conversion efficiency and the equipment manufacturing cost
    - o Briefly describe the fidelity of the thermodynamic performance and manufacturing cost models used in the abovementioned projections

#### b. Innovation and Impact

- Describe how the proposed effort represents an innovative and potentially transformational solution to the technical challenges posed by the FOA.

- Describe how the proposed concept is favorably differentiated from alternative hybrid system configurations (e.g. direct/indirect, gas turbine/reciprocating engine/etc., o-SOFC, p-SOFC, etc.)

- To the extent possible, provide quantitative metrics in a table that compares the proposed technology concept to current and emerging technologies and to the Technical Performance Targets in Section I.F of the FOA.

### c. PROPOSED WORK

- Describe the final deliverable(s) for the project and the overall technical approach used to achieve project objectives.

- Discuss alternative approaches considered, if any, and why the proposed approach is most appropriate for the project objectives.

- Describe the background, theory, simulation, modeling, experimental data, or other sound engineering and scientific practices or principles that support the proposed approach. Provide specific examples of supporting data and/or appropriate citations to the scientific and technical literature.

- Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?
    - Describe the current state of the component/sub-system technology required for the successful commercial realization of the proposed concept
    - Describe the major thermodynamic performance, cost and/or durability risks to the realization of the above described component/sub-system technology

- Identify techno-economic challenges to be overcome for the proposed technology to be commercially relevant.

### d. TEAM ORGANIZATION AND CAPABILITIES

- Indicate the roles and responsibilities of the organizations and key personnel that comprise the Project Team.

- Provide the name, position, and institution of each key team member and describe in 1-2 sentences the skills and experience that he/she brings to the team.

- Identify key capabilities provided by the organizations comprising the Project Team and how those key capabilities will be used in the proposed effort.

- Identify any complimentary activities that are supportive of the overall goals of the FOA

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

## D. Content and Form of Full Applications

[TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018]

## E. Content and Form of Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018]

## 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 NOVEMBER 2018]

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

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

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

# V. Application Review Information

## A. Criteria

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

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

### 1. Criteria for Concept Papers

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

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

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

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- Sufficiency of technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches and how technical risk will be mitigated;
- Clearly defined project outcomes and final deliverables; and

- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among team members supporting the proposed project.

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

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

### 2. Criteria for Full Applications

[TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018]

### 3. Criteria for Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018]

## B. Review and Selection Process

### 1. Program Policy Factors

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

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

II. **Relevance to ARPA-E Mission Advancement.** Project contributes to one or more of ARPA-E's key statutory goals:

a. Reduction of US dependence on foreign energy sources;
b. Stimulation of domestic manufacturing/U.S. Manufacturing Plan;
c. Reduction of energy-related emissions;
d. Increase in U.S. energy efficiency;
e. Enhancement of U.S. economic and energy security; or
f. Promotion of U.S. advanced energy technologies competitiveness.

III. **Synergy of Public and Private Efforts**.
a. Avoids duplication and overlap with other publicly or privately funded projects;
b. Promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer; or
c. Increases unique research collaborations.

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

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

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

### 2. ARPA-E Reviewers

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

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

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

### 3. ARPA-E Support Contractor

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

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

## C. Anticipated Announcement and Award Dates

[TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018]

# VI. Award Administration Information

## A. Award Notices

### 1. Rejected Submissions

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

### 2. Concept Paper Notifications

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

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

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

#### 3. FULL APPLICATION NOTIFICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018]

### B. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN NOVEMBER 2018]

## VII. AGENCY CONTACTS

### A. COMMUNICATIONS WITH ARPA-E

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

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

- ARPA-E will post responses on a weekly basis to any questions that are received that have not already been addressed at the link above. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- ARPA-E will cease to accept questions approximately 10 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted approximately one business day in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- Responses are published in a document specific to this FOA under "CURRENT FUNDING OPPORTUNITIES – FAQS"" on ARPA-E's website (http://arpa-e.energy.gov/faq).

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

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

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

## B. DEBRIEFINGS

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

# VIII. Other Information

## A. 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 Research and Development Act of 1974, 42. U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below)*.

- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues "class patent waivers" under which large businesses and foreign entities that meet certain stated requirements, such as cost sharing of at least 20%, may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion. If the class waiver does not apply, a party may request a waiver in accordance with 10 C.F.R. §784.

- GOGOs are subject to the requirements of 37 C.F.R. Part 501.

- Determination of Exceptional Circumstances (DEC): Each Applicant is required to submit a U.S. Manufacturing Plan as part of its Full Application. The U.S. manufacture provision included in Attachment 2 of an award is included as part of the U.S. Manufacturing Plan. If selected, the U.S. Manufacturing Plan may be incorporated into the award terms and conditions for domestic small businesses and nonprofit organizations. DOE has determined that exceptional circumstances exist that warrants the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to the extent necessary to implement and enforce the U.S. Manufacturing Plan. For example, the commitments and enforcement of a U.S. Manufacturing Plan may be tied to subject inventions. Any Bayh-Dole entity (domestic small business or nonprofit organization) affected by this DEC has the right to appeal it. The DEC is dated September 9, 2013 and is available at the following link: http://energy.gov/gc/downloads/determination-exceptional-circumstances-under-bayh-dole-act-energy-efficiency-renewable.

## 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.

### 3. U.S. Manufacturing Requirement

ARPA-E requires that awards address whether 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) are to be substantially manufactured in the United States by Project Teams and their licensees. The requirement varies depending upon whether an awardee is a small business, University or other type of awardee. The Applicant may request a modification or waiver of the U.S. Manufacturing Requirement.

## 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 in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

## I. Protected Personally Identifiable Information

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

- Social Security Numbers in any form;
- Place of Birth associated with an individual;
- Date of Birth associated with an individual;
- Mother's maiden name associated with an individual;
- Biometric record associated with an individual;
- Fingerprint;

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

## J. Compliance Audit Requirement

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

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

## IX. GLOSSARY

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

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

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

**Cost Sharing:** is the portion of project costs from non-Federal sources that are borne by the Prime Recipient (or non-Federal third parties on behalf of the Prime Recipient), rather than by the Federal Government.

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

**DOE:** U.S. Department of Energy.

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

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

**FOA:** Funding Opportunity Announcement.

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

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

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

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

**PI**: Principal Investigator.

**Project Team:** A Project Team consists of the Prime Recipient, Subrecipients, and others performing inventive supportive work that is part of an ARPA-E project.

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

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

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

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

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