FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

Reliable Electricity Based on ELectrochemical Systems (REBELS)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0001026
CFDA Number 81.135

FOA Issue Date:	November 25th, 2013
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, January 1st, 2014
Submission Deadline for Concept Papers:	5 PM ET, January 8th, 2014
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	TBD
Submission Deadline for Full Applications:	TBD
Submission Deadline for Replies to Reviewer Comments:	TBD
Expected Date for Selection Notifications:	TBD
Total Amount to Be Awarded	Approximately $30 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

- For eligibility criteria, see Section III.A of the FOA.
- For cost share requirements under this FOA, see Section III.B of the FOA.
- To apply to this FOA, Applicants must register with and submit application materials through ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov/Registration.aspx). For detailed guidance on using ARPA-E eXCHANGE, see Section IV.H.1 of the FOA.
- Applicants are responsible for meeting each submission deadline. Applicants are strongly encouraged to submit their applications at least 48 hours in advance of the submission deadline.
- ARPA-E will not review or consider noncompliant or nonresponsive applications. For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 and III.C.2 of the FOA.

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

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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 include the following: o Technology Description (2 pages max.) o Addendum (2 pages max.)	Mandatory	IV.C	5 PM ET, January 8th, 2014
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN February 2014]	Mandatory	IV.D	TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN February 2014]	Optional	IV.E	TBD

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy, is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358), to support the creation of transformational energy technologies and systems through funding and managing Research and Development (R&D) efforts. Originally chartered in 2007, the Agency was first funded through the American Recovery and Reinvestment Act of 2009. Since that time, the Agency has funded about 285 projects totaling approximately $770 million across the entire energy technology landscape.[1]

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

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

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

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

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

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

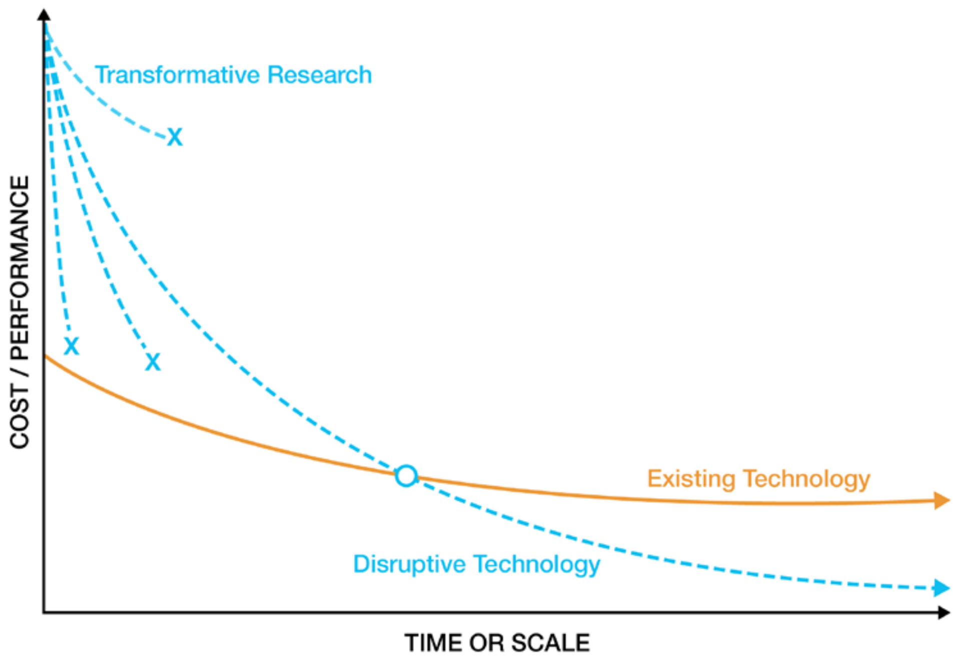

Figure 1: Description of transformational and disruptive technologies in terms of cost, performance, and scale. ARPA-E supports research that establishes new learning curves. A transformational technology becomes disruptive after passing the tipping point.

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

ARPA-E funded technology has the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. Energy technologies typically become disruptive at maturity rather than close to inception and the maturation of nascent technologies often require significant incremental development to drives the technology down its natural learning curve to its ultimate equilibrium (see Figure 1 above). Such development might include modification of the technology itself, the means to produce and distribute that technology, or both. Thus, while early incarnations of the automobile were transformational in the sense that they created a fundamentally new learning curve for transportation, they were not disruptive, because of the unreliability and high cost of early automobiles. Continuous, incremental refinement of the technology ultimately led to the Ford Model T: as the first affordable, reliable, mass-produced vehicle, the Model T had a disruptive effect on the transportation market.

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

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

ARPA-E will not support basic research aimed at discovery and fundamental knowledge generation, nor will it undertake large-scale demonstration projects of existing technologies. ARPA-E is not a substitute for existing R&D organizations within the Department of Energy, but rather complements existing organizations by supporting R&D objectives that are transformational and translational. Applicants interested in receiving basic research financial assistance should work with the Department of Energy's Office of Science (http://science.energy.gov/). Similarly, projects focused on the improvement of existing technology platforms may be appropriate for support by the applied programs – for example, the Office of Energy Efficiency and Renewable Energy (http://www.eere.energy.gov/), the Office of Fossil Energy (http://fossil.energy.gov/), the Office of Nuclear Energy (http://nuclear.energy.gov/), and the Office of Electricity Delivery and Energy Reliability (http://energy.gov/oe/office-electricity-delivery-and-energy-reliability).

B. PROGRAM OVERVIEW

This program, Reliable Electricity Based on ELectrochemical Systems (REBELS), seeks to disrupt traditional learning curves for distributed stationary power generation, by introducing technology concepts that have the potential for significantly lower cost and that are capable of performance superior to current distributed generation technologies. Fuel cell technologies have been touted for decades due to their high chemical-to-electrical conversion efficiencies and potential for near-zero greenhouse gas emissions when fueled by hydrogen or operated as part of a carbon capture and storage (CCS) process. However, fuel cell technologies have not achieved widespread adoption due primarily to high cost relative to incumbent combustion technologies. In this program, ARPA-E seeks to fund transformational fuel cell devices that operate in an *intermediate temperature* range in an attempt to 1) create new pathways to achieve an installed cost to the end-user of less than $1,500/kW at moderate production volumes,[2] and 2) create new fuel cell functionality to increase grid stability and integration of renewable energy technologies such as wind and solar.

Existing DOE programs in the Office of Energy Efficiency and Renewable Energy (EERE) and the Office of Fossil Energy have focused on low temperature proton exchange membrane (PEM) fuel cells and high temperature solid oxide fuel cells (SOFC) for transportation and stationary power applications, respectively. Over the past ten years, these programs have advanced PEM and SOFC technologies in both performance and cost. While the technologies that emerge from the REBELS program will be at earlier stages of their learning curves than current PEM and SOFC technologies, ARPA-E's view is that fuel cell operation in an intermediate temperature regime could enable unique opportunities for cost reduction and performance improvement with multiple pathways to market adoption. This program builds on materials advances over the past decade that have broadened the number of available electrolytes and electrodes beyond traditional PEM and SOFC temperature ranges. ARPA-E aims to bring together different scientific communities, such as fuel cell materials scientists, inorganic and polymer chemists, researchers working on novel approaches to activate carbon/hydrogen bonds for fuel processing, and experts in fuel cell fabrication methods to quickly advance intermediate temperature fuel cells to working prototypes and engage with stakeholders who can drive these devices towards market adoption. ARPA-E also aims to fundamentally alter the paradigm of fuel cell systems by creating new functionality in fuel cell technology such as battery-like response to transient loads and electrochemical production of liquid fuels.

Centralized Stationary Power Generation: Advantages and Disadvantages

The current system for delivering electricity consists primarily of fuel-to-electricity generation at coal, natural gas combined cycle (NGCC), and nuclear plants, followed by transport across the U.S. electrical grid via transmission and distribution (T&D) networks, and finally delivery to the end-user. This baseload generation is complemented by spin reserves such as simple-cycle natural gas turbines that provide additional capacity during peak use hours, as well as other

[2] "Installed cost to the end-user" includes cost of the complete system, tax, and markup; "moderate production volume" is defined as less than 50,000 units per year.

ancillary services such as voltage regulation, load following, system protection, etc. The primary benefit of this centralized approach to power generation is that the conversion of chemical energy to electricity via combustion or fission is more efficient and cost effective at scale. For example, a state-of-the-art 510 MW NGCC plant, can have electrical efficiencies on the order of 51-55% on a higher heating value (HHV) basis.[3] In contrast, smaller simple cycle gas turbines with a capacity of 1-10 MW have electricity efficiencies of roughly 21-29% HHV.[4]

Disadvantages of the current centralized electricity generation system include:

- Significant greenhouse gas emissions: more than 2 billion tons of CO_2 are released annually from the electricity production sector.[5]
- T&D losses and expenses: on average, 7% of the electricity produced in the U.S. is lost during transmission and distribution.[6] This results in 218 million tons of CO_2 emissions (equal to 62 coal plants) and $25 billion of lost revenue.[7] Additionally, an estimated $1.5-2.0 trillion in T&D investments will be required between now and 2030 to build new power corridors and maintain existing ones.[8]
- Grid vulnerability due to natural disasters and terrorist attacks, including cyber attacks.[9]
- Difficulty in integrating renewable energy technologies, discussed in further depth below.

The Need to Integrate an Increasing Amount of Renewable Energy with the Grid

Installation of variable and intermittent generation technologies such as solar photovoltaic and wind turbines poses a fundamental challenge to centralized power generation. Matching generation and load in the grid becomes difficult with high levels of variable energy resources (VER) because they are non-dispatchable;[10] vary on the time scales of minutes, hours, and days; and can unpredictably ramp up and down due to weather events. In addition, VER are located on the edge of the grid or far from load centers where inadequate transmission resources exist connecting the generation to the load. This is becoming an increasingly critical issue, as the installation of renewable electricity generators such as solar and wind is a growing trend in the

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[3] http://www.netl.doe.gov/KMD/cds/Disk50/NGCC%20Technology_051507.pdf
[4] "Catalog of CHP Technologies," U.S. Environmental Protection Agency Combined Heat and Power Partnership (2008).
[5] http://www.eia.gov/tools/faqs/faq.cfm?id=77&t=11
[6] http://www.eia.gov/tools/faqs/faq.cfm?id=105&t=3
[7] Assumes 1.67 lbs. CO_2/kWh (average of coal and natural gas) and a retail electricity price of $0.10/kWh.
[8] "A Natural Gas Enabled Smart Grid: Opportunities for Distributed Energy Resources," Dan Rastler, Electric Power Research Institute, presented at 13th Annual SECA Workshop (2012).
[9] "Electric Grid Vulnerability: Industry Responses Reveal Security Gaps," http://democrats.energycommerce.house.gov/sites/default/files/documents/Report-Electric-Grid-Vulnerability-2013-5-21.pdf (2013).
[10] R. Masiello, et al., "Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid," prepared for the California Energy Commission (CEC-500-2010-010) (2010).

United States,[11] driven in part by renewable portfolio standards (RPS) in 27 states and net metering policies and other efficiency incentives in 43 states.[12]

Today, integration of VER into the grid is usually accomplished by using dispatchable, quick-ramping thermal generators to smooth the variability over a "balancing region." This preserves reliability, power quality, and counters VER ramp events and errors in weather forecasting.[13] Inadequate balancing reserves and/or transmission resources have already led to curtailment of renewable power in both the Electric Reliability Council of Texas (ERCOT) and the Bonneville Power Administration's (BPA) system.[14] In 2012, however, the Federal Energy Regulatory Commission (FERC) issued Order 764 which adopted reforms intended to better integrate VER with the grid.[15]

Addressing Challenges of the Grid through Distributed Generation

The challenges associated with centralized power generation described above indicate the potential for distributed generation (DG) to be a complementary and beneficial strategy for power delivery. There are over 12 million DG units in the United States, with a capacity greater than 200 GW.[16] However, the majority of this capacity exists as emergency backup generators that are seldom operated. Nevertheless, increased DG in the U.S. would have multiple benefits, including peak load reduction, reactive power and voltage support, reduced T&D congestion, improved power quality, and reduced grid vulnerability.[16] Many companies, including some large retail, technology, and manufacturing companies and the owners of large building complexes such as hospitals are implementing DG because of energy cost savings and increased reliability.[17]

Another benefit of DG is the capability to utilize waste heat generated in the process of converting chemical energy to electricity. Combined heat and power (CHP, or cogeneration) and combined cooling, heating, and power (CCHP, or trigeneration) has the potential to increase efficiency to greater than 80% at residential homes, commercial businesses, and industrial facilities. There is approximately 82 GW of CHP capacity in the United States,[18] which reduces annual energy consumption by 1.9 quadrillion British Thermal Units (Quads) and CO_2 by

[11] U.S. Energy Information Administration, "Annual Energy Review," http://www.eia.gov/totalenergy/data/annual/pdf/aer.pdf, Figure 8.2a (2011).
[12] http://www.dsireusa.org/documents/summarymaps/net_metering_map.pdf
[13] "MIT Study on The Future of the Electric Grid," http://web.mit.edu/mitei/research/studies/the-electric-grid-2011.shtml (2011).
[14] R. Wiser and M. Bolinger, "Wind Technologies Market Report," http://www1.eere.energy.gov/wind/pdfs/2011_wind_technologies_market_report.pdf (2011).
[15] http://www.ferc.gov/whats-new/comm-meet/2012/062112/E-3.pdf
[16] "The Potential Benefits of Distributed Generation and Rate-Related Issues that May Impede their Expansion," U.S. Department of Energy (2007).
[17] http://www.fuelcells.org/uploads/BusinessCaseforFuelCells.pdf; http://www.modernhealthcare.com/article/20130907/MAGAZINE/309079851
[18] "Combined Heat and Power: A Clean Energy Solution," U.S. DOE and EPA (2012).

248 million metric tons.[19] The White House is currently supporting a new challenge to install 40 GW of new, cost-effective DG by 2020. The expected benefits include $10 billion in energy savings, 1 Quad reduction in energy consumption, and a CO_2 reduction of 150 million metric tons.[18]

Current fossil fuel DG technologies (or 'prime movers') include reciprocating engines, gas turbines, microturbines, internal combustion engines, and fuel cells. Each technology varies in terms of operational parameters such as: nameplate capacity, operating temperature, start-up time, electrical efficiency, CHP efficiency, installed cost, operations & maintenance (O&M) costs, and maintenance intervals. An end-user's decision to install a particular DG prime mover will be based on these attributes, as well as factors such as technical requirements, fuel type, and geography, along with state and local incentives.

The Need for Small, Reliable Distributed Generation

Given Carnot limits for combustion technologies and traditional economies of scale, the efficiency of a DG unit generally increases and the installation cost decreases, as the overall system size increases. In fact, most units that demonstrate an electrical efficiency greater than 30% HHV and an installation cost lower than $2,000/kW are 300 kW or larger. This is illustrated in Figure 2, where the desirable combination of cost and efficiency exists in the center of the figure. There is a noticeable gap as system size decreases.

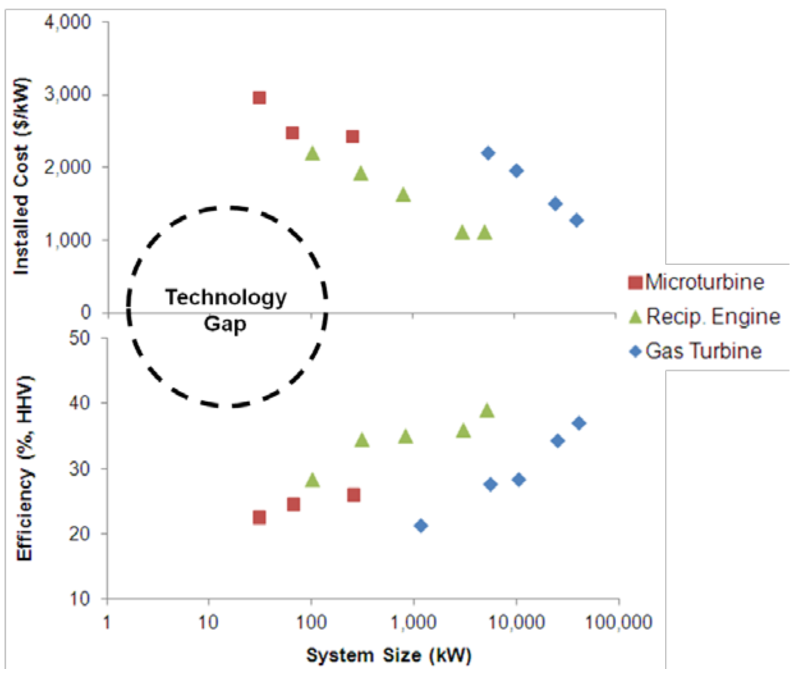

Figure 2: Installation cost and electrical efficiency of various DG prime movers as a function of system size, indicating a technology gap of low cost, high-efficiency prime movers at smaller sizes (adapted from[4])

[19] "Combined Heat and Power: Effective Energy Solutions for a Sustainable Future," Oak Ridge National Laboratory, ONRL/TM-2008/224 (2008).

Another factor that has favored installation of larger DG units is maintenance intervals and the associated O&M cost. As shown in Table 1, the maintenance intervals for smaller DG prime movers such as microturbines and particularly reciprocating engines entail more frequent service for continuously operating generators. ARPA-E seeks a DG prime mover below 100 kW that has an optimal balance of high efficiency, low installed cost, and low maintenance requirements for long-term operation.

Maintenance Intervals (hrs)	
Gas Turbines	4,000-8,000
Microturbine	5,000-8,000
Recip. Engine	500-2,000 (inspection) 8,000 (overhaul)
Fuel Cells	20,000-40,000+

Table 1: Maintenance intervals for various DG prime movers[4]

There are several niche applications that could benefit from small, efficient, reliable DG and serve as potential first markets. One such example is backup power for telecommunications sites such as cell phone towers and call centers. Fuel cells represent a superior option for such applications because they have lower emissions, are quieter, and require less on-site maintenance.[20] Another potential early market for small fuel cell systems is electrification of natural gas wellpads. Because of the low value of 'stranded' natural gas, wellpads are currently operating by pneumatic devices that operate on the pressure of the gas. However, this gas is then vented to the atmosphere, resulting in more than 20 million tons of CO_2 equivalent emissions and $3.2 billion in lost revenue.[21] Reliable 3-5 kW fuel cells could be used to provide continuous power to the wellpad, reduce emissions, and recover lost revenue associated with vented gas.

Despite these promising applications, the potential performance improvements associated with fuel cells for small DG applications have yet to be fully realized due to cost and fuel supply barriers. First, fuel cells remain expensive, and cost/benefit calculations made by businesses are greatly affected by Federal, state, and/or local incentives. For example, the current Federal Investment Tax Credit (ITC) for fuel cells subsidizes 30% of the system cost or $3,000/kW, whichever value is smaller. This ITC is valid for systems built until the end of 2016.[22] Second, most of the fuel cell systems described above operate directly on pure hydrogen fuel that must be produced (typically via steam methane reforming), transported to the site, stored in gas tanks, and then refilled or swapped when empty. A simpler and longer-term option would be a direct connection to a natural gas line and use of an on-site fuel processor. This scenario would expand the functionality of fuel cells beyond backup power, provide superior reliability, and enhance siting flexibility for commercial installations such as telecom, data centers, etc. These first markets would enable a larger fuel cell supply chain and increased manufacturing volume, thereby establishing a pathway towards applications such as residential DG and CHP.

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[20] Fuel Cells for Backup Power in Telecommunications Facilities," http://www.hydrogen.energy.gov/pdfs/44520.pdf (2009).

[21] "Petroleum and Natural Gas Systems 2011 Data Summary," EPA, http://www.epa.gov/climatechange/Downloads/ghgemissions/2013Workshop/supporting-info-2011-data-summary.pdf

[22] http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F

Closing the Cost and Performance Fuel Cell Gap

Electrochemical devices such as fuel cells are a potential solution for small, reliable DG because they are not limited by the Carnot cycle. The electrical efficiency of small fuel cell systems is typically 30-43% HHV, compared to small combustion technologies that do not exceed 30% HHV.[4] While fuel cell efficiencies are typically lower than large NGCC power plants, additional factors mentioned above such as T&D losses, as well as gains due to CHP or CCHP configurations, mean that GHG emissions from small fuel cell systems can meet or be lower than the GHG emissions of the best centralized power generation technologies today, as shown in Figure 3. Additionally, the potential for ultra-low emissions from renewably-derived hydrogen fuel or as part of a CCS process means that fuel cells are likely to be a key technology for a zero carbon future.

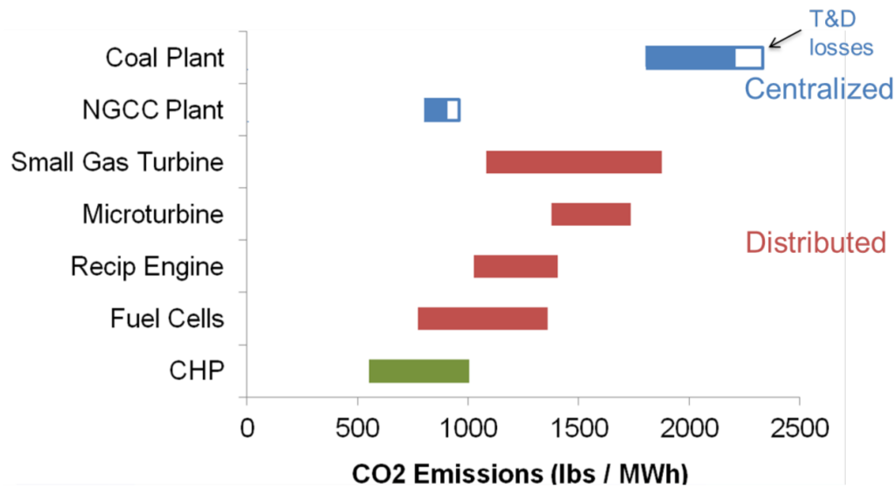

Figure 3: CO_2 emissions from centralized, distributed, and CHP generation technologies[4]

The U.S. government for many years has funded fuel cells and hydrogen storage research with a focus on transportation and stationary power applications. The materials emphasis of these programs has mostly been on high temperature SOFCs based on yttria-stabilized zirconia (YSZ) electrolytes and low temperature PEMFCs based on Nafion®. While progress has been made in improving the performance of both devices, state-of-the-art SOFCs and PEMFCs still face technical and commercialization challenges. The high operating temperatures and poor thermal cycling characteristics (> 700 ^{o}C) of SOFCs has confined them to steady-state, baseload applications, and also require high cost materials for the balance of plant.[23,24] Traditional PEMFCs are restricted to low operating temperatures (< 100 ^{o}C) and require expensive platinum group metal (PGM) catalysts, ultra-pure hydrogen fuel, and a complex system for membrane hydration. PEMFCs also have issues related to long-term durability, corrosion, and fuel

[23] S.M. Haile, Acta Mater. 51 (2003) 5981-6000
[24] D.J.L. Brett, et al., Chem. Soc. Rev 37 (2008) 1568-78

crossover.[23,25] The strengths as well as challenges of these devices are summarized in Table 2 below. Current fuel cell systems have an installed cost of at least $4,000/kW,[26] which has limited their widespread adoption into the distributed power generation market.

Table 2: Advantages and challenges of low temperature PEMFCs and high temperature SOFCs

	PEMFC	SOFC
Strengths	• Rapid startup • Cycling ability • Roll-to-roll processing	• High power density • Higher electrical efficiency • Inexpensive catalysts • Fuel flexibility
Challenges	• Expensive PGM catalysts required • Fuel limited to H_2 • Complex fuel processing required • Low quality heat for CHP	• Performance & cost of interconnects and seals • Limited to static, baseload operation • Stack lifetime

Alternative fuel cell electrolytes and electrode materials do exist and can, in fact transport a wide variety of ionic species, including: oxide, hydronium, and carbonate ions, structural or defect protons, or other hydrogen carriers such as hydroxide, ammonium, or H_2S. Plotting the temperature of operation versus the ionic conductivity of several of the electrolytes, Norby identified a common deficiency in electrolyte performance, dubbed "Norby's Gap," in the range of 300-600°C.[27] In the 14 years since that paper was published, many new electrolyte materials with ionic conductivities >10^{-2} S/cm in the range 200-600°C have been identified and several of these materials have been developed into full-scale fuel cell systems. Examples include solid acid fuel cells,[28] low temperature SOFCs,[29] intermediate temperature alkaline fuel cells,[30] and intermediate temperature proton conducting fuel cells.[31] Novel electrodes and electrolytes for intermediate temperature SOFCs were summarized in a recent review.[32] These recent materials advances support the view that operation in an intermediate temperature range between traditional PEMFC and SOFC devices is possible, and could afford lower cost systems for small DG applications.

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[25] B.C.H. Steele, A. Heinzel, Nature 414 (2001) 345-52
[26] National Fuel Cell Research Center, University of California-Irvine, http://www.nfcrc.uci.edu/2/FUEL_CELL_INFORMATION/FCexplained/challenges.aspx
[27] T. Norby, Solid State Ionics 125 (1999), 1-11.
[28] http://www.technologyreview.com/news/421277/cheap-diesel-powered-fuel-cells/
[29] E.D. Wachsman, et al., Science 334 (2011) 935-939.
[30] T. Hibino, K. Kobayashi, J. Mat. Chem. A 1 (2013), 1134-1140.
[31] Y. Huang, et al., J. Mat. Chem. 22 (2012), 22452-22458.
[32] A. Aguadero, et al., J. Mater. Sci. 47 (2012), 3925-3948.

The benefits of operation in an intermediate temperature range higher than traditional PEMFCs (> 100°C), include the use of simpler and lower cost fuel processor subsystems by incorporating some degree of in-situ fuel reformation, as well as reduced fuel purity requirements due to a greater tolerance to CO and other reformate impurities. Conventional thinking has held intermediate temperature operation to be incompatible with fuel flexibility, as formation of coke from hydrocarbons becomes increasingly favorable below 650 ^{o}C. That may be the case for traditional Ni/YSZ composite anodes, but there are multiple concepts using CeO_2-based systems,[33,34] as well as biological approaches to C/H bond activation[35] that could enable intermediate temperature fuel processing. On the other hand, operating below traditional SOFC operating temperatures (< 650°C) could enable the use of lower-cost interconnects and seals, and increase stack lifetime. Other potential benefits of intermediate temperature operation are summarized in Table 3. While ARPA-E recognizes that intermediate temperature operation is not a solution for all fuel cell cost and performance issues, the combination of lower cost materials, simpler balance of plant, and more dynamic operation suggests great opportunity in this technology space.

Table 3: Potential benefits of fuel cell operation in an intermediate temperature range

Potential benefits of intermediate temperature operation	
Compared to low temperature FCs	**Compared to high temperature FCs**
• Simpler fuel processor design • Greater tolerance to CO and other impurities • Lower or zero need for PGM catalysts • Increased fuel flexibility • Greater CHP potential	• Reduced interdiffusion and interfacial reaction product formation • Reduced degradation from differences in thermal expansion coefficients at interfaces • Ability to operate dynamically • Lower cost interconnects and seals • Longer stack lifetime • Reduced coarsening of nanostructured materials

Increasing Fuel Cell Functionality: The Potential to Ease Renewables Integration with the Grid

The concept of stationary fuel cells reducing grid instability has been explored in the past, with focus on demand control techniques, DC-DC converters, changes in steady-state fuel utilization, and integration with batteries or ultracapacitors.[36,37] For example, Meacham and coworkers modeled fuel cell ramp rates ranging from 0.01 to 100 kW/s and concluded that a fuel cell system without energy storage would have to respond at a rate of approximately 100 kW/s to avoid perturbing the grid. Such ramp rates are highly unlikely based on traditional fuel cell

[33] T. Suzuki, et al., Energy & Env. Sci. 4 (2011) 940-943.
[34] H. Zhu, et al., Int. J. Hydr. Energy 38 (2013) 3741-3749.
[35] V. Dong, "Methane Activation: Inspiration from Nature," http://arpa-e.energy.gov/sites/default/files/documents/files/2_Methane%20activation%20inspiration%20from%20nature%20-%20Dong.pdf
[36] J.R. Meacham, et al., Journal of Power Sources 156 (2006) 472-479.
[37] A.E. Auld, et al., IEEE Transactions on Energy Conversion 24 (2009) 617-625.

technologies, as fuel starvation and thermal fluctuations would likely occur due to fuel flow delays associated with the slow response of the fuel processor.[38] An expansion of fuel cell functionality beyond the DG/CHP scenarios outlined above could increase the benefits of fuel cells as a complementary technology for integrating renewables with the grid. One such example of increased functionality is increasing the dynamic response time of fuel cells to be closer to that of a battery, which could be accomplished via in-situ storage of charge using storage materials as electrodes, or using the device to couple different electrochemical reactions. If a selected membrane material is coupled with the appropriate catalysts, hybrid fuel cell/battery devices become possible. For example, a SOFC with vanadium oxide electrodes can store charge for a short time in the electrode.[39] Alkaline fuel cells with MnO_2 and a metal hydride as electrodes can also both generate and store charge.[40,41,42] Because electrochemical processes such as gas-phase diffusion, adsorption, and dissociation are not required when charge is already stored in an electrode, such devices could ramp to peak power, rather than operating on continuous power output as is done with state-of-the-art fuel cells. Integrating the functionality of fuel cells and batteries at the system level, one electrochemical device could incorporate the functionality of both, reducing the number of components in the overall system and therefore cost.

Another example of increased functionality in a fuel cell would be to use it for the electrochemical production of liquid fuels. The use of such a device would depend on its chemistry and location. One example would be for the device to be coupled to a variable renewable generator such as a wind turbine or solar panel. Excess electricity generated by the renewable resource could be used to electrochemically convert gaseous fuel such as methane to a liquid chemical to be stored in bulk. At a later time, this liquid fuel could be fed into a fuel cell (or other power generating device) in order to meet power demands. This example allows excess VER to be converted to a dispatchable energy resource. In another embodiment, a fuel cell could be located at a natural gas wellpad or digester, with the fuel cell providing power (electrical output) and also converting excess natural gas to a more easily transported, and higher value liquid chemical. In these examples, the electrochemical cell can be operated with electricity as an input *or* an output, depending on the electrochemical reactions coupled by the device. If the reaction is thermodynamically favorable, the device could potentially produce chemicals and electricity simultaneously.

Summary

The creation of novel, intermediate temperature fuel cell materials could not only lead to a decrease in the cost of fuel cells, but could enable a reinvention of fuel cell technology as a completely new, multi-functional device. These hybrid electrochemical systems, could, for example, include in-situ charge storage to enable a more dynamic response to transients.

[38] F. Mueller, et al., J. Power Sources 187 (2009) 452-460.
[39] Q. Van Overmeer, et al., Nano Lett. 12 (2012) 3756-3760
[40] J. Hong, et al., J. Power Sources, 161 (2006) 753-760.
[41] C. Wang, et al., J. Electrochem Soc. 151 (2004) A260-A264.
[42] D. Chartouni, et al., Intl. J. Hydrogen Energy 27 (2002) 945-952.

Moreover, intermediate temperature operation opens up the use of never-before-possible, higher operating temperature hydrogen storage materials with high gravimetric storage densities. Magnesium hydride (MgH_2) for example, dehydrides at 300 ^oC and has a H_2 storage capacity of approximately 7.6 wt%.[43] This and other materials with high capacities and higher dehydride temperatures are not compatible with the lower temperature operation of PEMFC, further underscoring the utility of intermediate temperature operation. In terms of fuel production, higher temperature devices such as SOFCs reform natural gas to H_2 and CO_2 gas using either a fuel processor and/or the anode itself. While lower temperature devices have little-to-no intrinsic fuel processing capability, at intermediate temperatures, there is the possibility to pursue chemistries other than complete oxidation of methane, such as partial oxidation and other reactions as discussed below.

C. PROGRAM OBJECTIVES

The overall objective of the REBELS program is to disrupt traditional learning curves for distributed stationary power generation, introducing technology concepts based on intermediate temperature fuel cells (ITFCs) that have the potential for significantly lower cost and are capable of performing outside the scope of current distributed generation technologies. The first specific objective of this FOA is to seek new solid electrolytes, electrocatalysts, fuel processing methods, and fuel cell manufacturing techniques to create ITFCs with high power density, a 10-year stack lifetime, and the potential to achieve an ultimate target for installed cost to the end-user of $1,500/kW at moderate production volumes, and a nearer-term cost target of $2,000-3,000/kW for niche commercial markets acting as early adopters. The second specific objective of this FOA is to expand the functionality of traditional fuel cells to benefit the stability of the grid and integration of renewable resources by creating either ITFCs that generate power and store charge in an electrode for battery-like response to transients, or hybrid systems capable of electrochemically converting methane or other gaseous hydrocarbons to liquid fuels.

D. TECHNICAL CATEGORIES OF INTEREST

This program is focused on supporting efficient, reliable, and fast-response ITFCs in one or more of the following three categories:

CATEGORY 1: ITFCs for DG applications

This category focuses on the creation of a 100 W short stack prototype that demonstrates high efficiency and reliability, as well as a pathway to lower cost via a combination of inexpensive materials and reduction of overall system components. The final performance metrics must be met with the use of a non hydrogen gas or liquid fuel. Projects in this category will focus on two of the three subsystems in an overall fuel cell system: the fuel processor and the fuel cell

[43] L. Schlapbach and A. Züttel, Nature 414 (2001) 353-358.

stack. The third subsystem, power electronics, is the focus of other ARPA-E programs such as Agile Delivery of Electrical Power Technology (ADEPT), and will not be a focus of this program.

Examples of potential research thrusts include, but are not limited to:

- Intermediate temperature solid state electrolytes with high ionic conductivity and stability
- High performance electrodes/electrocatalysts
- Novel concepts for activating C/H bonds beyond traditional steam methane reforming
- High-throughput methods of fabricating fuel cell stacks without high temperature sintering.

The ideal team in this Category will have relevant experience in multiple areas, rather than expertise in only one piece of the system (e.g. the electrolyte or the fuel processor).

CATEGORY 2: ITFCs with in-situ charge storage for dynamic response
This category focuses on fuel cells that also store charge in an electrode, enabling battery-like response to transient loads. For example an electrochemical cell consisting of a metal hydride anode, proton-conducting electrolyte, and cathode could operate either as a fuel cell or a rechargeable metal hydride/air battery. An intermediate operating temperature (200-500 ^{o}C) increases the number of potential anode materials, as there are many more materials available above 100 ^{o}C with hydrogen storage capacities > 7.5 wt%. Such a device could have a much faster response to transient loads that are currently addressed by integrating fuel cells with either batteries or ultracapacitors. This new concept would integrate fuel cells and charge storage at the device-level rather than system-level, thus reducing the number of system components required for a given functionality. Similar functionality is envisioned for oxygen-based electrolytes with redox-active electrode species. <u>**Note that these and all technology examples in this FOA are meant only to illustrate principles; they are *not* meant to prescribe or limit the technical approaches that might receive an award though the REBELS program.**</u>

CATEGORY 3: ITFCs with fuel production capability
This category focuses on ITFCs that can also convert methane or other gaseous hydrocarbons to liquid fuels using excess renewable energy. Whereas high temperature operation typically results in reversible conversation of H_2 and O_2 to water or complete oxidation of CH_4 to H_2 and CO_2, intermediate temperatures could enable partial oxidation of CH_4 to CH_3OH or the formation of carbon-carbon bonds to make other liquid fuels or higher value chemicals. Examples could include conversion of methane or another hydrocarbon fuel to syngas, methanol, benzene, ethers, olefins, or other organics. The proposed choice of electrochemical half-reactions would determine whether electricity is an input or output in this device. Either would acceptable for this category. This particular use of an electrochemical cell likens it to a small-scale gas-to-liquids reactor (GTL). The economics of GTL reactors were presented in the ARPA-E Reducing Emissions Using Methanotrophic Organisms for Transportation Energy

(REMOTE) FOA.[44] Traditional GTL plants can only be built at large scale in order to achieve economic payback. These plants generally have a production capacity of >10^4 barrels of oil equivalent per day (bpd), and high capital cost of the reactor per unit capacity, usually >$100,000/bpd.[45] Electrochemical GTL has the potential to outperform these systems in cost, throughput, and efficiency while keeping the footprint of the reactor small. A competitive system would have lower cost per capacity, high process intensity, high selectivity, and long lifetime.

E. TECHNICAL PERFORMANCE TARGETS

Proposed technical plans must show a well-justified, realistic potential for the technology to meet or exceed the quantitative Technical Performance Targets described below. Prototypes developed under the work plan should credibly approach all the listed technical targets. In addition to the specific Technical Performance Targets, there are several categories that require the applicant to state a target value on their own.

CATEGORY 1: ITFCs for DG applications

End-of-project deliverables: (1) A short stack prototype of at least 100 W and consisting of at least 5 cells. The input fuel cannot be hydrogen. (2) A detailed cost model projecting system installed cost for early market adopters and at moderate production volumes.

ID	Category	Value
1.1	Desired operating temperature range	200-500 ^{o}C
1.2	Current density at 70% of Nernst voltage	> 200 mA/cm^2
1.3	Electrical efficiency at rated power	>50%
1.4	Startup time	< 10 minutes
1.5	Transient response	< 1 minute
1.6	Minimum stack testing time	1,000 hours
1.7	Power degradation rate	< 0.3% per 1,000 hours
1.8	Platinum group metal (PGM) total loading	< 0.1 mg PGM / cm^2 electrode area

Supplemental Explanation of Category 1 Performance Targets

1.1 Fuel cells operating in the desired temperature range are strongly preferred, though ARPA-E may consider unique systems that operate at temperatures outside this range.

1.2 As measured on final short stack deliverable.

1.3 Ratio of DC output to net LHV of fuel.

1.4 Time required from cold start to rated power.

[44] https://arpa-e-foa.energy.gov/FileContent.aspx?FileID=4f84a273-85d7-447c-9ffc-811282a97eb0
[45] P. J. A. Tijm, *Gas to liquids, Fischer-Tropsch, Advanced Energy technology, Future's Pathway* (2010).

1.5 From 10% to 90% of rated power.

1.7 Degradation rate to be calculated using first polarization curve and a current density of at least 150 mA/cm^2 as a baseline. Degradation testing will include effects of steady-state operation as well as transient operation, startup, and shutdown.

1.8 Higher PGM content will be considered for selection if the application demonstrates an overall cost reduction (e.g. by elimination of an external reformer).

CATEGORY 2: ITFCs with in-situ charge storage for dynamic response

End-of-project deliverables: (1) An electrochemical cell prototype; unlike Category 1, the fuel may be hydrogen. The ***same cell*** must be capable of both fuel cell mode ***and*** battery mode operation but are not expected to run concurrently. (2) A high-level cost model projecting system installed cost for early market adopters and at moderate production volumes, to include the cost benefits of the in-situ charge storage.

ID	Category	Value
2.1	Desired operating temperature	200-500 ^oC
2.2	Current density at 70% of Nernst voltage	> 200 mA/cm^2
2.3	Minimum stack testing time	100 hours
2.4	PGM total loading	< 0.1 mg PGM / cm^2 electrode area
2.5	Battery response time	< 1 second
2.6	Time at rated power	15 minutes
2.7	Battery cycling degradation	80% of loaded capacity retained after 30 cycles
2.8	Battery mode recharge time	< 1 hour
2.9	Self-discharge rate	< 5% of loaded capacity after 12 hours
2.10	Mode switching temperature	To be specified by the applicant

Supplemental Explanation of Category 2 Performance Targets

2.1 Fuel cells operating in the desired temperature range are strongly preferred, though ARPA-E may consider unique systems that operate at temperatures outside this range.

2.2 In fuel cell mode.

2.3 Continuous, steady-state operation in fuel cell mode.

2.4 Higher PGM content will be considered for selection if the application demonstrates an overall cost reduction (e.g. by elimination of an external reformer).

2.6 Length of time the cell can discharge in battery-mode at rated power.

2.10 Temperature change (if applicable) to enable battery mode from fuel cell mode.

CATEGORY 3: ITFCs with fuel production capability

End-of-project deliverables: (1) An electrochemical cell prototype; the input fuel must be methane or another gaseous hydrocarbon. Applicants may propose one electrochemical cell that operates in fuel cell mode and fuel production mode ***or*** one fuel cell and a separate electrochemical fuel production cell. (2) A high-level cost model projecting system installed cost for early market adopters and at moderate production volumes, to include the cost benefit of fuel production capability.

ID	Category	Value
3.1	Desired operating temperature	200-500 ^oC
3.2	Current density at 70% of Nernst voltage	> 200 mA/cm^2
3.3	Continuous cell operations	> 100 hours
3.4	Minimum cell area	> 100 cm^2
3.5	Current density (during fuel production)	> 100 mA/cm^2
3.6	Cell cost per rate of product output	< $100,000/bpd
3.7	Process intensity	> 0.1 bpd/ft^3
3.8	Product yield	> 50 %
3.9	Carbon efficiency	> 50%
3.10	Desired product(s)	To be specified by applicant
3.11	Volumetric product output per cell	To be specified by applicant (L/day)

Supplemental Explanation of Category 3 Performance Targets

3.1 In fuel cell mode. Fuel cells operating in the desired temperature range are strongly preferred, though ARPA-E may consider unique systems that operate at temperatures outside this range.

3.2 In fuel cell mode.

3.3 Continuous, steady-state operation in fuel cell mode.

3.4 Minimum cell area for demonstration of liquid hydrocarbon production must be at least 100 cm^2 (roughly 4”× 4”).

3.5 Minimum current density in liquid hydrocarbon production mode determines the maximum rate of product output, see Table 4 (below) for sample calculations.

3.6 Cell cost per rate of product output defines the materials cost of the reactor per unit of production capacity of the reactor in $/bpd, see Table 4 (below) for sample calculations. For this calculation, reasonable assumptions must first be made to estimate a real cost for cell materials ($/cm^2) before the final cell cost per rate of product output.

3.7 Process intensity defines the volumetric size of the reactor system per unit production capacity. State-of-the-art large-scale GTL reactors (e.g. Shell-Pearl) have a process intensity on the order 0.02 bpd/ft^3. To calculate process intensity for an electrochemical reactor, a unit cell thickness should be assumed and documented, see Table 4 for sample calculations.

3.8 Product yield Y_P (= $X_R \cdot S_P$) refers to the single-pass percentage product obtained from the reaction, and is calculated from the fraction of reactant converted per pass X_R and the selectivity for the desired products of the reaction S_P; where, $X_R = \frac{m_{R,in} - m_{R,out}}{m_{R,out}}$,

$S_R = \frac{m_{P,out}}{m_{R,in} - m_{R,out}}$, m is mass and subscripts P and R are products and reactants, respectively.

3.9 Carbon efficiency is calculated from $\eta_C = \frac{m_{C,Products}}{m_{C,Reactants}}$ where $m_{C,Products}$ and $m_{C,Reactants}$ are the mass of carbon in the desired product and in the reactants, respectively. Applicants should provide a well-justified, realistic potential of achieving a carbon efficiency of greater than 50% for fuel production.

3.10 Desired liquid hydrocarbon product, the basic chemical reactions, and thermodynamics (free energy, enthalpy, and entropy) should be specified by the applicant.

3.11 Applicants should note assumptions and calculate the anticipated volumetric product output (mL/day) for a single, 200 cm^2 prototype cell.

Table 4: Sample calculations for Category 3

Description	Symbol	Unit	Sample Products pentane	benzene	methanol
Reaction			$5CH_4=C_5H_{12} + 4H_2$	$6CH_4=C_6H_6 + 9H_2$	$CH_4 + 0.5O_2 = CH_3OH$
Number of electrons	n	mol/mol	8	18	2
Faraday constant	F	C/mol	96485	96485	96485
Membrane active area	A	cm^2	100	100	100
Cell unit thickness*	ℓ	cm	1	1	1
Current density	j	A/cm^2	0.100	0.100	0.100
Molar mass product	M	g/mol	72.2	78.1	32.0
Density of product	ρ	g/mL	0.626	0.877	0.792
Enthalpy of combustion	$\Delta_c H^{\ominus}$	kJ/mol	3509	3273	715
Volumetric product output	$P_V = jAM/\rho nF$ (×86400)	mL/day	129	44	181
Areal product output	$P_A = j\Delta_c H^{\ominus}/nF$ (÷70.8)	bpd/cm^2	6.42E-06	2.66E-06	5.23E-06
Process intensity	$PI = j\Delta_c H^{\ominus}/nF\ell$ (×400)	bpd/ft^3	0.18	0.08	0.15
Cell materials cost*	C_A	$\$/cm^2$	0.50	0.20	0.50
Cell cost per product output	C_A/P_A	$/bpd	77,881	75,136	95,540

*Assumed
Barrel of oil equivalent (boe) = 6.12 GJ
Barrel of oil per day (bpd) = 70.8 kJ/s

F. APPLICATIONS SPECIFICALLY NOT OF INTEREST

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

- Applications that focus on reducing PGM catalyst loading of traditional PEM stacks.
- Applications that focus solely on reducing the operating temperature of traditional SOFCs by reducing the thickness of the electrolyte.
- Applications that fall outside the technical categories of interest and technical parameters specified in Section I.D and Section I.E of the FOA.
- Applications that were already submitted to pending ARPA-E FOAs.
- Applications that are not scientifically distinct from applications submitted to pending ARPA-E FOAs.

- Applications for basic research aimed at discovery and fundamental knowledge generation.
- Applications for large-scale demonstration projects of existing technologies.
- Applications for proposed technologies that represent incremental improvements to existing technologies.
- Applications for proposed technologies that are not based on sound scientific principles (*e.g.,* violates a law of thermodynamics).
- Applications that do not address at least one of ARPA-E's Mission Areas (see Section I.A of the FOA).
- Applications for proposed technologies that are not transformational, as described in Section I.A of the FOA and as illustrated in Figure 1 in Section I.A of the FOA.
- Applications for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress (see Figure 1 in Section I.A of the FOA).
- Applications that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $30 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 12-18 awards under this FOA. ARPA-E may issue one, multiple, or no awards.

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

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be in September 2014, or as negotiated.

ARPA-E encourages applications stemming from ideas that still require proof-of-concept R&D efforts as well as those for which some proof-of-concept demonstration already exists. All applicants should propose projects of sufficient scope and duration to achieve the technical targets for the deliverables in one or more of the categories presented in this FOA.

Applications requiring proof-of-concept R&D should submit evidence of an idea, containing an appropriate cost and project duration plan that is described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. If awarded, such projects should expect a rigorous go/no-go milestone early in the project associated with the proof-of-concept demonstration. Applicants proposing projects for which some initial proof-of-concept demonstration already exists should submit concrete data that supports the probability of success of the proposed project. ARPA-E will provide support at the highest funding level only for applications with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

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

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

B. ARPA-E FUNDING AGREEMENTS

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[46] Accordingly, ARPA-E has substantial involvement in the direction of every project, as described in Section II.C below.

1. Cooperative Agreements

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[47]

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

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

2. Funding Agreements with FFRDCs, GOGOs, and Federal Instrumentalities[48]

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

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

When a FFRDC or non-DOE/NNSA GOGO is a *member* of a Project Team, ARPA-E executes a funding agreement directly with the FFRDC or non-DOE/NNSA GOGO and a single, separate

[46] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[47] The Prime Recipient is the signatory to the funding agreement with ARPA-E.
[48] DOE/NNSA GOGOs are not eligible to apply for funding, as described in Section III.A of the FOA.

Cooperative Agreement with the rest of the Project Team. Notwithstanding the use of multiple agreements, the Prime Recipient under the Cooperative Agreement is the lead organization for the entire project, including all work performed by the FFRDC or non-DOE/NNSA GOGO and the rest of the Project Team.

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

3. TECHNOLOGY INVESTMENT AGREEMENTS

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

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

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

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

4. GRANTS

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

C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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

- ARPA-E does not limit its involvement to the administrative requirements of the ARPA-E funding agreement. Instead, ARPA-E has substantial involvement in the direction and redirection of the technical aspects of the project as a whole. Project teams must adhere to ARPA-E technical direction and comply with agency-specific and programmatic requirements.

- ARPA-E may intervene at any time to address the conduct or performance of project activities.

- During award negotiations, ARPA-E Program Directors establish an aggressive schedule of quantitative milestones and deliverables that must be met every quarter. Prime Recipients document the achievement of these milestones and deliverables in quarterly technical and financial progress reports, which are reviewed and evaluated by ARPA-E Program Directors (see Attachment 4 to ARPA-E's Model Cooperative Agreement, available at http://arpa-e.energy.gov/?q=project-guidance/award). ARPA-E Program Directors visit each Prime Recipient at least twice per year, and hold periodic meetings, conference calls, and webinars with Project Teams. ARPA-E Program Directors may modify or terminate projects that fail to achieve predetermined technical milestones and deliverables.

- ARPA-E reviews reimbursement requests for compliance with applicable Federal cost principles and Prime Recipients' cost share obligations. Upon request, Prime Recipients are required to provide additional information and documentation to support claimed expenditures. Prime Recipients are required to comply with agency-specific and programmatic requirements. Please refer to Section III. B of the FOA for guidance on proof of cost share commitment and cost share reporting.

- ARPA-E works closely with Prime Recipients to facilitate and expedite the deployment of ARPA-E-funded technologies to market. ARPA-E works with other Government agencies and nonprofits to provide mentoring and networking opportunities for Prime Recipients. ARPA-E also organizes and sponsors events to educate Prime Recipients about key barriers to the deployment of their ARPA-E-funded technologies. In addition, ARPA-E establishes collaborations with private and public entities to provide continued support for the development and deployment of ARPA-E-funded technologies.

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

III. Eligibility Information

A. Eligible Applicants

1. Individuals

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[49] as the lead for a Project Team,[50] or as a member of a Project Team.

2. Domestic Entities

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

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

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

Non-DOE/NNSA GOGOs are eligible to apply for funding as a member of a Project Team, but not as a Standalone Applicant or as the lead organization for a Project Team.

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

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

3. Foreign Entities

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the

[49] A Standalone Applicant is an Applicant that applies for funding on its own, not as part of a Project Team.
[50] 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.
[51] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 1995 are not eligible to apply for funding as a Prime Recipient or Subrecipient.

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

4. Consortium Entities

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

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

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

B. Cost Sharing[52]

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

1. Base Cost Share Requirement

[52] Please refer to Section III.B of the FOA for guidance on cost share payments and reporting.

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

2. INCREASED COST SHARE REQUIREMENT

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

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

3. REDUCED COST SHARE REQUIREMENT

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

- A domestic educational institution or domestic nonprofit applying as a Standalone Applicant is required to provide at least 5% of the Total Project Cost as cost share.

- Project Teams composed exclusively of domestic educational institutions, domestic nonprofits, and/or FFRDCs are required to provide at least 5% of the Total Project Cost as cost share.

- Project Teams where domestic educational institutions, domestic nonprofits, and/or FFRDCs perform greater than or equal to 80%, but less than 100%, of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity (such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.

- Projects that do not meet any of the above criteria are subject to the minimum cost share requirements described in Section III.B of the FOA.

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[53] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.
[54] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

4. Legal Responsibility

Although the cost share requirement applies to the Project Team as a whole, the funding agreement makes the Prime Recipient legally responsible for paying the entire cost share. The Prime Recipient's cost share obligation is expressed in the funding agreement as a static amount in U.S. dollars (cost share amount) and as a percentage of the Total Project Cost (cost share percentage). If the funding agreement is terminated prior to the end of the project period, the Prime Recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination. ARPA-E requires all recipients to contribute cost share in proportion with each submitted invoice over the life of the program.

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

5. Cost Share Allocation

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

6. Cost Share Types and Allowability

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G 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 <u>not</u> use the following sources to meet its cost share obligations:

- Revenues or royalties from the prospective operation of an activity beyond the project period;
- Proceeds from the prospective sale of an asset of an activity;

- Federal funding or property (e.g., Federal grants, equipment owned by the Federal Government); or

- Expenditures that were reimbursed under a separate Federal program.

In addition, Project Teams may not use independent research and development (IR&D) funds[55] 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 10 C.F.R. parts 600 and 603 for additional guidance on cost sharing, specifically 10 C.F.R. §§ 600.30, 600.123, 600.224, 600.313, and 603.525-555.

7. Cost Share Contributions by FFRDCs and GOGOs

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

8. Cost Share Verification

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

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

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

ARPA-E will not review or consider noncompliant Concept Papers, including Concept Papers submitted through other means, Concept Papers submitted after the applicable deadline, and incomplete Concept Papers. A Concept Paper is incomplete if it does not include required information, such as the funding category (see Section II.A of the FOA). ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Full Applications are deemed compliant if:

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

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

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploaded all required documents to ARPA-E eXCHANGE by the deadline stated in the FOA.

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

2. RESPONSIVENESS CRITERIA

ARPA-E performs a preliminary technical review of Concept Papers and Full Applications. Any "Applications Specifically Not of Interest," as described in Section I.F of the FOA, are deemed nonresponsive and are not reviewed or considered.

3. LIMITATION ON NUMBER OF APPLICATIONS

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

IV. Application and Submission Information

A. Application Process Overview

1. Registration in ARPA-E eXCHANGE

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

2. Concept Papers

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

ARPA-E performs a preliminary review of Concept Papers to determine whether they are compliant and responsive, as described in Section III.C of the FOA. ARPA-E makes an independent assessment of each compliant and responsive Concept Paper based on the criteria and program policy factors in Sections V.A.1 and V.B.1 of the FOA.

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

3. Full Applications

Applicants must submit a Full Application by the deadline stated in the FOA. Applicants will have approximately 30 days from receipt of the Encourage/Discourage notification to prepare and submit a Full Application. Section IV.D of the FOA provides instructions on submitting a Full Application.

ARPA-E performs a preliminary review of Full Applications to determine whether they are compliant and responsive, as described in Section III.C of the FOA. ARPA-E reviews only compliant and responsive Full Applications.

4. Reply to Reviewer Comments

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

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

5. "Down-Select" Process

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

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

6. Selection for Award Negotiations

ARPA-E carefully considers all of the information obtained through the application process and makes an independent assessment of each compliant and responsive Full Application based on the criteria and program policy factors in Sections V.A.2 and V.B.1 of the FOA. ARPA-E may select or not select a Full Application for award negotiations. ARPA-E may also postpone a final selection determination on one or more Full Applications until a later date, subject to availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

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

7. Mandatory Webinar

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

B. Application Forms

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

C. Content and Form of Concept Papers

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

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

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

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

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

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

SECTION	PAGE LIMIT	DESCRIPTION
Technology Description	2 pages maximum	• Applicants are required to describe succinctly: o The proposed technology, including its basic operating principles and how it is unique and innovative; o The proposed technology's target level of performance (Applicants should provide technical data or other support to show how the proposed target could be met); o The current state-of-the-art in the relevant field and application, including key shortcomings, limitations, and challenges; o How the proposed technology will overcome the shortcomings, limitations, and challenges in the relevant field and application; o The potential impact that the proposed project would have on the relevant field and application; o The key technical risks/issues associated with the proposed technology development plan; and o The impact that ARPA-E funding would have on the proposed project.
Addendum	2 pages maximum	• Applicants should provide an estimate of the proposed budget and period of performance for their project • Applicants may provide graphs, charts, or other data to supplement their Technology Description. • Applicants are required to describe succinctly the qualifications, experience, and capabilities of the proposed Project Team, including: o Whether the Principal Investigator (PI) and Project Team have the skill and expertise needed to successfully execute the project plan; o Whether the Applicant has prior experience which demonstrates an ability to perform R&D tasks of similar risk and complexity; o Whether the Applicant has worked together with its teaming partners on prior projects or programs; and o Whether the Applicant has adequate access to equipment and facilities necessary to accomplish the R&D effort and/or clearly explain how it intends to obtain access to necessary equipment and facilities.

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

F. INTERGOVERNMENTAL REVIEW

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

G. FUNDING RESTRICTIONS

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

H. OTHER SUBMISSION REQUIREMENTS

1. USE OF ARPA-E eXCHANGE

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

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

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

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

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

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

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

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

V. Application Review Information

A. Criteria

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

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

1. Criteria for Concept Papers

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

- The extent to which the proposed quantitative material and/or technology metrics demonstrate the potential for a transformational and disruptive (not incremental) advancement in one or more energy-related fields;

- The extent to which the Applicant demonstrates a profound understanding of the current state-of-the-art and presents an innovative technical approach that significantly improves performance relative to the current state-of-the-art; and

- The extent to which the Applicant demonstrates awareness of competing commercial and emerging technologies and identifies how the proposed concept/technology provides significant improvement over existing solutions.

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

- The extent to which the proposed approach is unique and innovative;

- The feasibility of the proposed work;

- The extent to which the Applicant proposes a sound technical approach to accomplish the proposed R&D objectives;

- The extent to which project outcomes and deliverables are clearly defined; and

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

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

Impact of the Proposed Technology Relative to State of the Art	50%
Overall Scientific and Technical Merit	50%

2. Criteria for Full Applications

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

3. Criteria for Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

B. Review and Selection Process

1. Program Policy Factors

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

2. ARPA-E Reviewers

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

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

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

3. ARPA-E Support Contractor

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

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

C. Anticipated Announcement and Award Dates

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

VI. Award Administration Information

A. Award Notices

1. Rejected Submissions

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

2. Concept Paper Notifications

ARPA-E promptly notifies Applicants of its determination to encourage or discourage the submission of a Full Application. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. Due to the anticipated volume of applications, ARPA-E is unable to provide feedback on Concept Papers.

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

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

3. Full Application Notifications

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

B. Administrative and National Policy Requirements

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

C. Reporting

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

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

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

- ARPA-E will post responses on a weekly basis to any questions that are received. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- ARPA-E will cease to accept questions approximately 5 business days in advance of each submission deadline. Responses to questions received before the cutoff will be posted approximately one business day in advance of the submission deadline. ARPA-E may re-phrase questions or consolidate similar questions for administrative purposes.

- Responses are posted to "Frequently Asked Questions" on ARPA-E's website (http://arpa-e.energy.gov/faq).

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

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

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

B. DEBRIEFINGS

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

VIII. OTHER INFORMATION

A. FOAS AND FOA MODIFICATIONS

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

B. OBLIGATION OF PUBLIC FUNDS

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

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

C. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

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

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

D. Retention of Submissions

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

E. Marking of Confidential Information

ARPA-E will use data and other information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments strictly for evaluation purposes. Applicants should not include confidential, proprietary, or privileged information in their Concept Papers, Full Applications, or Replies to Reviewer Comments unless such information is necessary to convey an understanding of the proposed project.

Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

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

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

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

F. Title to Subject Inventions

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

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions. If they elect to retain title, they must file a patent application in a timely fashion.

- All other parties: The Federal Non Nuclear Energy Act of 1974, 42. U.S.C. 5908, provides that the Government obtains title to new inventions unless a waiver is granted (*see below)*.

- Class Waiver: Under 42 U.S.C. § 5908, title to subject inventions vests in the U.S. Government and large businesses and foreign entities do not have the automatic right to elect to retain title to subject inventions. However, ARPA-E typically issues “class patent waivers” under which large businesses and foreign entities that meet certain stated requirements may elect to retain title to their subject inventions. If a large business or foreign entity elects to retain title to its subject invention, it must file a patent application in a timely fashion.

G. Government Rights in Subject Inventions

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

1. Government Use License

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

2. March-In Rights

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

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

- The owner or licensee has not taken or is not expected to take effective steps to achieve practical application of the invention within a reasonable time;

- The owner or licensee has not taken action to alleviate health or safety needs in a reasonably satisfactory manner;

- The owner has not met public use requirements specified by Federal statutes in a reasonably satisfactory manner; or

- The U.S. Manufacturing requirement has not been met.

H. RIGHTS IN TECHNICAL DATA

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

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.

- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years. Such data should be clearly marked as described in Section VIII.E of the FOA. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

I. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

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

- Social Security Numbers in any form;
- Place of Birth associated with an individual;

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

J. ANNUAL COMPLIANCE AUDITS FOR FOR-PROFIT ENTITIES

[TO BE INSERTED BY FOA MODIFICATION IN February 2014]

IX. GLOSSARY

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

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

ARPA-E: Advanced Research Projects Agency-Energy.

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

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

DOE: U.S. Department of Energy.

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

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

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

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

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

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

PI: Principal Investigator.

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

R&D: Research and development.

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

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

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

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

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