FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

CREATING INNOVATIVE AND RELIABLE CIRCUITS USING INVENTIVE TOPOLOGIES AND SEMICONDUCTORS (CIRCUITS)

Announcement Type: ~~Initial Announcement~~ Modification 01
Funding Opportunity No. DE-FOA-0001727
CFDA Number 81.135

Funding Opportunity Announcement (FOA) Issue Date:	January 9, 2017
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, Friday, February 10, 2017
Submission Deadline for Concept Papers:	5 PM ET, ~~Monday, February 20, 2017~~ Tuesday, February 21, 2017
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, TBD
Submission Deadline for Full Applications:	5 PM ET, TBD
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, TBD
Expected Date for Selection Notifications:	TBD
Total Amount to Be Awarded	Approximately $20 million, 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.

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

- For detailed guidance on compliance and responsiveness criteria, see Sections III.C.1 through III.C.4 of the FOA.

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MODIFICATIONS

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

Mod. No.	Date	Description of Modifications
01	01/10/2017	• Extended the Submission Deadline for Concept Papers to February 21, 2016, see Cover page and Required Documents Checklist.

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REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must not exceed 4 pages in length and must include the following: o Concept Summary o Innovation and Impact o Proposed Work o Team Organization and Capabilities	Mandatory	IV.C	5 PM ET, ~~Monday, February 20, 2017~~ Tuesday, February 21, 2017
Full Application	[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]	Mandatory	IV.D	5 PM ET, TBD
Reply to Reviewer Comments	[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]	Optional	IV.E	5 PM ET, TBD

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

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

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

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

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

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

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

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

B. PROGRAM OVERVIEW

1. SUMMARY

Development of advanced power electronics with unprecedented functionality, efficiency, reliability, and form factor will help provide the U.S. a critical technological advantage in an increasingly electrified world economy. The CIRCUITS (Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors) program seeks to accelerate the development and deployment of a new class of efficient, lightweight, and reliable power converters based on wide bandgap (WBG) semiconductors through transformational system-level advances that enable effective operation at high switching frequency, high temperature, and low loss. Previous efforts by ARPA-E and others have primarily focused on WBG material and device development without focused consideration and redesign of the circuit topology. Such solutions do not fully exploit the potential performance improvements enabled by this new class of power

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

semiconductor devices. Areas of particular interest for the CIRCUITS program include novel circuit topologies, advanced control and drive electronics, and innovative packaging. Such technological breakthroughs would catalyze the adoption of higher performance power converters in various critical applications (motor drives, automotive, power supplies, data centers, aerospace, ship propulsion, rail, distributed energy, and the grid) that offer significant direct and indirect energy savings and emissions reductions across electricity generation, transmission and distribution, and load-side consumption. Coupling novel and advanced circuit topologies with leading edge materials such as WBG semiconductor devices has the capacity to catalyze disruptive improvements for power electronics and subsequently for the U.S. economy.

2. BACKGROUND

Electricity generation currently accounts for 40% of primary energy consumption in the U.S.,[2] and over the next 25 years is projected to increase more than 50% worldwide.[3] Electricity continues to be the fastest growing form of end-use energy. Power electronics are responsible for controlling and converting electrical power to provide optimal conditions for transmission, distribution, and load-side consumption. Estimates suggest that the fraction of electricity processed through power electronics could be as high as 80% by 2030 (including generation and consumption), approximately a twofold increase over the current proportion.[4] Development of advanced power electronics with exceptional efficiency, reliability, functionality, and form factor will provide the U.S. with a competitive advantage in deployment of advanced energy technologies. Additionally, widespread integration of innovative converters offers substantial energy saving opportunities both directly, by inherently more efficient designs, and indirectly, by facilitating higher levels of adoption for fundamentally higher performing materials. High impact opportunities exist across a variety of applications, including:

Motor Drives**:** Across all sectors, electric motors account for approximately 40% of total U.S. electricity demand.[5] It is estimated that 40-60% of currently installed electric motors could benefit from variable frequency drives (VFDs),[6] which enable efficient adaptation to speed and torque demands. Depending on the application, incorporation of VFDs can reduce energy consumption by 10-30%.[7] Conventional VFDs for high power applications are bulky and occupy significant space. Power density and efficiency can be improved, and the overall system cost reduced, by using WBG-based VFDs.

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[2] U.S. Energy Information Administration, Monthly Energy Review (March, 2015)
[3] U.S. Energy Information Administration, International Energy Outlook 2016 (May, 2016)
[4] L.M. Tolbert, et al. Power Electronics for Distributed Energy Systems and Transmission and Distribution Applications: Assessing the Technical Needs for Utility Applications. Oak Ridge, TN: Oak Ridge National Laboratory (2005)
[5] Waide, P.; Brunner, C. U. Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems. IEA (2011)
[6] Energy Efficiency Roadmap for Electric Motors and Motor Systems. *Energy Efficient End-use Equipment*, IEA (2015)
[7] Energy Efficiency and Power Electronics. Danfoss, ATV Seminar, March 1, 2012

Automotive: Power electronics such as traction inverters, DC boost converters, and on-board battery chargers are critical elements in hybrid and electric vehicles (EVs), impacting energy efficiency in two ways: directly through switching and other losses, and indirectly by adding volume and weight. WBG inverters can reduce both direct and indirect losses by operating at higher switching frequencies, efficiencies, and temperatures.[8] As a result, 15% improvement in energy efficiency has been predicted for representative hybrid EVs employing SiC traction inverters, with even larger energy savings possible given greater degrees of drivetrain electrification.[9] Assuming aggressive market adoption of EVs in the U.S., use of WBG vehicle power electronics could save as much as 1 quadrillion Btu per year by 2050 relative to conventional Si-based systems.[10] Additionally, efficient, lightweight, and low-cost DC fast charging infrastructure (≥120 kW) enabled by WBG converters will advance the commercial viability of EVs, which, in conjunction with a cleaner electricity generation portfolio, has the potential to significantly reduce the one quarter of total U.S. greenhouse gas emissions that stem from the transportation sector.[11]

Data Centers: Energy consumption in data centers accounts for approximately 2% of electricity use in the U.S.[12] The power delivery architecture of most modern data centers consists of a line frequency transformer, low voltage power distribution network, centralized backup unit, and inefficient voltage regulators.[13] Strategies to improve energy efficiency range from integration of lower loss power converters to complete redesign of the power delivery network.[14] The latter approach often involves converting higher voltages at the rack level, where space is limited and proper thermal management is imperative, to reduce transmission losses and the number of conversion stages. High power density converters based on WBG devices can be key enablers for these more efficient systems, and operation at higher temperature can reduce cooling loads and further boost data center grid-to-chip efficiency.

Aerospace: Longer, thinner, and lighter wings can reduce fuel consumption and carbon emissions by 50% relative to current commercial aircraft.[15] Such a reduction would save

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[8] Hamada, K. et al. SiC-Emerging Power Device Technology for Next-Generation Electrically Powered Environmentally Friendly Vehicles. *IEEE Transactions On Electron Devices* (2015)
[9] Zhang, H. et al. Impact of SiC Devices on Hybrid Electric and Plug-In Hybrid Electric Vehicles. *IEEE Transactions on Industry Applications* (2011)
[10] U.S. Department of Energy. Quadrennial Technology Review (2015)
[11] Williams, J.H. et al. Pathways to Deep Decarbonization in the United States (2014)
[12] Shehabi, A. et al. United States Data Center Energy Usage Report. Berkeley, CA: Lawrence Berkeley National Laboratory (2016)
[13] Zhabeloval, G. et al. Data center energy efficiency and power quality: an alternative approach with solid state transformer. *41st Annual conference of the IEEE Industrial Electronics Society* (2015)
[14] Candan, E. et al. A Series-Stacked Power Delivery Architecture with Isolated Differential Power Conversion for Data Centers. *IEEE Transactions On Power Electronics* (2016)
[15] Slimmed Down Aircraft Wing Expected to Reduce Fuel and Emissions by 50%. NASA, accessed November 29, 2016, https://www.nasa.gov/image-feature/ames/slimmed-down-aircraft-wing-expected-to-reduce-fuel-and-emissions-by-50

approximately 1 quadrillion Btu of energy per year across the U.S. fleet at current demand.[16] Achieving this transformative wing design requires electromechanical actuators that are small and lightweight with robust operation over a wide temperature range.[17] Moreover, electrification of environmental controls, fuel pumps, brakes, and de-icing systems can further reduce weight and increase efficiency through elimination of engine bleed and pneumatic/hydraulic systems.[18] WBG-based converters, with high gravimetric and volumetric power density and high temperature operation, offer a pathway to achieving significant energy savings in air transport by reducing weight in more-electric aircraft and enabling new paradigms in body design.

***Distributed Energy Resources*:** In grid applications, such as solar photovoltaic (PV) and wind, as well as the emerging fields of high voltage direct current (HVDC) and flexible alternating current transmission systems (FACTS), power conditioners are required to process and control the flow of electricity by supplying voltages and currents in a form that is optimally suited to the load. Power electronics are responsible for a loss of approximately 4% of all of the electricity generated in these applications and are the dominant point of failure for installed systems. For instance, a typical maximum conversion efficiency for a silicon-based PV inverter is approximately 96% (AC output/DC input),[19] which drops significantly at operating temperatures above 50 °C. Novel WBG electronic circuits present a route to lower system-level costs by operating at higher switching frequencies that reduce the size of passive components and lower the overall system footprint. In addition, WBG circuits will increase system-level efficiency by allowing PV arrays to operate at higher voltages (e.g. medium voltage levels), enabling DC systems with fewer voltage conversions/transformers, replacing traditional combiner boxes with DC/DC converters, eliminating the need for on-site AC transmission lines, and ultimately allowing easier integration of energy storage solutions in the central substation. Together with a higher semiconductor operating temperature, the advantages of WBG electronics offer a pathway to more robust power converters with mean time to failure (MTTF) commensurate to the generation system lifetime (PV, wind, etc.). This will lower the equipment replacement cost and total plant O&M and have a significant impact on the levelized cost of energy in distributed resource applications.

The vast majority of current power electronics utilize silicon power semiconductors (e.g., insulated gate bipolar transistors (IGBTs)) that are slower, less energy efficient, and more constrained in operating temperatures than devices fabricated from WBG semiconductors, such as SiC and GaN, due to fundamental differences in material properties. Higher critical electric fields in WBG materials ($E_{br} \geq 200$ V/μm) enable thinner, more highly doped voltage-blocking layers in the associated devices, which can reduce on-resistance by two orders of magnitude in

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[16] Transportation Energy Data Book. Oak Ridge National Laboratory, 35th edition (2016)
[17] Thin-Wing Electromechanical Actuation (EMA) Demonstration. Department of Defense Air Force Research Lab.
[18] Wheeler, P. The More Electric Aircraft: Why Aerospace Needs Power Electronics. Accessed November 29, 2016, http://www.lboro.ac.uk/microsites/research/iemrc/Events%20write%20up/Power%20Electronics%2014.05.09/More_Electric_Aircraft_000.pdf
[19] SMA Technical Information, Efficiency and Derating, WKG-Derating-US-TI-en-15, Version 1.5, 2016

majority carrier architectures (e.g., Metal Oxide Field Effect Transistors, MOSFETs) relative to Si (E_{br} = 30 V/µm).[20] To mitigate conduction losses, high-voltage Si MOSFETs have large footprints that cause sizeable gate capacitance and substantial losses at high switching frequencies. Si IGBTs achieve smaller die footprints than MOSFETs by utilizing minority carriers and conductivity modulation, but the useful range of switching frequencies remains limited due to the relatively long lifetime of minority carriers. The inverse proportionality between switching frequency and passive component capacity results in low frequency silicon-based power converters with large form factors. High breakdown electric fields, low conduction losses, and short carrier lifetimes mean that WBG materials can achieve the same blocking voltage and on-resistance with a smaller footprint and at much higher frequency than a comparable Si device. The low intrinsic carrier concentration of WBG materials ($n_i \leq \sim 10^{-9}$ cm^{-3}) enables robust high-temperature performance due to low leakage currents at elevated temperatures. WBG semiconductors therefore provide a pathway to overcome the fundamental performance tradeoffs between blocking voltage, on-resistance, and switching frequency inherent to Si devices, enabling design of faster, more efficient, lighter, and smaller power converters with reduced cooling requirements.

Substantial technical progress has been made on WBG-based power switches over the past decade. Investments from the Department of Defense[21] and several DOE offices, including the Advanced Manufacturing Office,[22] the Office of Electricity Delivery and Energy Reliability GIGA program,[23] and the Vehicle Technologies Program,[24] have helped build early U.S. leadership and bring WBG devices closer to widespread adoption.

ARPA-E's Agile Delivery of Electrical Power Technologies (ADEPT) program, initiated in 2010, funded several teams to develop new WBG devices and demonstrate their efficacy in system demonstrations.[25] The ADEPT program successes were significant in advancing commercial applications of SiC and GaN devices. However, SiC and GaN device technologies have remained immature relative to Si and currently carry a substantial cost premium, limiting their widespread adoption.[26] Many of the largest opportunities for increased energy efficiency and reduced energy-related emissions exist in extremely cost-conscious industries, including

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[20] Heffner, A. et al. Recent Advances in High-Voltage, High-Frequency Silicon-Carbide Power Devices. Industry Applications Conference, 41st IAS Annual Meeting (2006)

[21] "DARPA Sets Tough Goals For The Wide-Bandgap Community," *Compound Semiconductor*, November 8, 2002

[22] Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office, "Wide Bandgap Semiconductor for Clean Energy Workshop: Summary Report," (Washington, DC: U.S. Department of Energy, 2012)

[23] Controlling the Flow: Next-Generation Power Electronics Systems for Tomorrow's Electric Grid. Office of Electricity Delivery and Energy Reliability (2015)

[24] Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program, *Multi-Year Program Plan 2011-2015,* December 2010 (Washington, DC: U.S. Department of Energy)

[25] "Agile Delivery of Electrical Power Technologies," ARPA-E, U.S. Department of Energy, accessed Nov. 28, 2016, http://arpa-e.energy.gov/?q=arpa-e-programs/adept

[26] R. Eden, "Market Forecasts for Silicon Carbide & Gallium Nitride Power Semiconductors," Presentation at 2013 Applied Power Electronics Conference and Exposition, Long Beach, CA (March 2013)

markets for railway traction drives, automotive applications, and industrial motors.[27,28,29] By the end of the ADEPT program, cost still remained a major barrier to the widespread adoption of WBG devices despite opportunities for superior performance.

ADEPT's successor program, Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems (SWITCHES), launched in 2013 and was designed to address key materials fabrication and architecture issues that drive costs for SiC and GaN devices, as well as evaluate early stage WBG power semiconductors such as diamond.[30] The goal was to enable the development of high voltage (>1200 V), high current (100 A) single die power semiconductor devices that, upon ultimately reaching scale, would have the potential to reach functional cost parity with silicon power transistors while also offering breakthrough relative circuit performance (low losses, high switching frequencies, and high temperature operation). These transformational technologies would reduce the barriers to ubiquitous deployment of low-loss WBG power semiconductor devices in stationary and transportation energy applications. One key target for the SWITCHES program is for WBG packaged devices to demonstrate a manufacturing cost of 0.1 $/A at 100A and 1200V, at which point they would be competitive with the best silicon IGBT devices in the same class (with an order of magnitude faster switching speeds).

ARPA-E's activity in WBG semiconductor development (including associated projects within the Solar ADEPT, OPEN 2012, and OPEN 2015 programs) has been complemented by efforts in other DOE departments such as the Office of Energy Efficiency and Renewable Energy's Advanced Manufacturing Office (AMO) and SunShot program. In particular:

AMO awarded $22M to five projects under the Next Generation Electric Machines: Megawatt Class Motors program aimed at emerging WBG technologies to advance large-scale motor control efficiency in energy-intensive industries. Additionally, AMO, as part of the National Network for Manufacturing Initiative, sponsors the Power America Institute led by North Carolina State University. With a budget of $70M, the program is set up to advance the manufacturing of WBG power electronics in the United States.[31]

To build capability in the field of WBG power electronics, AMO also provided funding to improve proficiency in the U.S. workforce through the DOE Traineeship in Power Engineering

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[27] "Railway Inverter with Hybrid SiC Power Module," *Power Electronics Europe* (October 5, 2012)
[28] Lowe M. et al. U.S. Adoption of High-Efficiency Motors and Drives: Lessons Learned. Center on Globalization, Governance and Competitiveness, Duke University (2010)
[29] Boutros, K. et al. GaN Power Electronics for Automotive Application. Paper presented at 2012 IEEE Energytech, Cleveland, OH, (May 2012)
[30] "Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High-Efficiency Systems," ARPA-E, U.S. Department of Energy, accessed Nov. 28, 2016, https://arpa-e.energy.gov/?q=arpa-e-programs/switches
[31] https://www.poweramericainstitute.org. Accessed Nov. 28, 2016

(Leveraging Wide Bandgap Power Electronics). Launched in 2015, the program has a total budget of almost $10M.[32]

Two projects associated with the DOE's SunShot Initiative, which focuses in part on PV power electronics development to enhance energy efficiency, include the 2011 program Solar Energy Grid Integration Systems - Advanced Concepts ($25.9M) and the 2015 program Sustainable and Holistic Integration of Energy Storage and Solar PV (SHINES, $15M). Both program FOAs reference ARPA-E and its associated projects in the field of power electronics as influencing the aim and scope of the activities.

In the private sector, converter level innovation was recently spurred through the 2014 Google/IEEE Little Box Challenge, a competition to design and test a 2 kW, single-phase inverter with a power density greater than 50 W/in^3 and demonstrating targets related to efficiency (>95%), electrical noise, and thermal performance.[33] More than 80 proposals reviewed by the IEEE and Google were down-selected to a cohort of 18 finalists with a range of backgrounds that included academia, large companies, start-ups, and individuals. The winner, CE&T Power's Red Electrical Devils, produced a 2kW inverter with a power density of 142.9 W/in^3 within a total volume of only 14.0 in^3 using GaN transistors and zero voltage switching. It should be noted that the vast majority of the leading designs utilized WBG devices and innovative circuit topologies, packaging and thermal strategies, control and driver ICs, and EMI mitigation methodologies to achieve the goals of the competition.

Government and private sector support of WBG device development has helped drive these promising power semiconductors down their technological learning curve. There are now several salient examples of high-power commercial products and prototypes employing WBG power devices. In 2014, Toyota, in conjunction with Denso, introduced a prototype SiC power control unit (PCU) for its Prius hybrid vehicles, demonstrating a 5% improvement in fuel economy over the standard JC08 Japanese drive cycle.[34] With respect to the goals of the CIRCUITS program, it should be noted that this state-of-the-art system was not fully optimized for WBG device operation, and opportunities remain for substantial improvement in efficiency and power density for EV PCUs.[8] ABB recently announced the release of its first ever SiC battery charger for rail applications that is 1/10 the size and 80% lighter than comparable Si models.[35] The charger utilizes soft switching control techniques to achieve high efficiency. As a final example, GE introduced the first 1500 V, multi-MW SiC inverter for utility-scale PV systems in

[32] https://energy.gov/eere/amo/articles/doe-traineeship-power-engineering-leveraging-wide-bandgap-power-electronics
[33] The Little Box Challenge. Google and IEEE, accessed December 1, 2016, https://littleboxchallenge.com/
[34] Toyota Global Newsroom. *Toyota Develops New Silicon Carbide Power Semiconductor with Higher Efficiency*. [Press release]. (May, 2014). Retrieved from http://newsroom.toyota.co.jp/en/detail/2656842.
[35] ABB, Product Group Traction. *ABB Launches Most Compact Silicon Carbide Battery Charger for All Rail Applications*. [Press release]. (2016). Retrieved from http://www04.abb.com/global/seitp/seitp202.nsf/0/0b6cbb63bb28d8a6c125802f00447994/$file/EN_Trade+press+release_Battery+charger+BORDLINE(R)+BC.pdf

2016.[36] The EU-weighted (an averaged operating efficiency over a yearly power distribution corresponding to middle-Europe climate) efficiency of 99.0% illustrates the exceptional performance of this system at partial load conditions.

To a large extent, previous R&D efforts have focused on WBG material and device development where advanced WBG power semiconductors, such as SiC and GaN, would be substituted for silicon, but mostly without focused consideration and redesign of the circuit topology. Direct replacement of Si devices by WBG semiconductors limits the potential improvements in power electronic performance metrics. Thus, there is now an opportunity to build on the successes from earlier programs and aim for both higher performance, as well as increased market penetration of these particularly promising technologies.

Given the capabilities of emerging WBG materials and devices, there are new opportunities for innovations in power electronics such as converter circuit topologies and architectures, resonant and soft switching, control techniques, integration and packaging, and system architectures. Recent advances have demonstrated high performance WBG semiconductor devices, but they have not yet achieved high rates of adoption because power circuits have not been designed that exploit their inherent advantages. Additionally, there are concerns about the cost and reliability of WBG semiconductor devices. New circuit topologies could be designed to fully extract the potential of WBG semiconductor devices while addressing cost and reliability concerns. An illustration of technological opportunities beyond device development is shown in Figure 1.

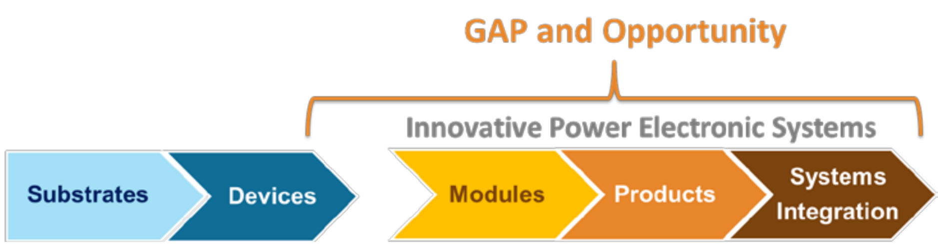

Figure 1. Opportunities of interest that harness recent advancements at the component level to enable transformational developments at the circuit and system levels.

This is an opportune time to leverage recent progress in electronic materials and devices to fully realize their benefits. The growing commercial availability of WBG devices, along with associated cost reductions and reliability improvements over the past several years, have paved the way for a new era in circuit design. Greater access to semiconductor die and advanced circuit components promotes collaboration between diverse communities to an extent not previously attainable with limited device supply. There are numerous precedents for advances in device technology requiring new approaches at the circuit and system level for significant proliferation of the technology. Recent programs in compound semiconductors have driven

[36] GE Power Conversion. *LV5+ 1500V Solar Inverter*. (2016). Retrieved from http://www.gepowerconversion.com/sites/gepc/files/GEA32649%20LV5%2B%20Solar%20Inverter%20(SiC)%20Data%20Sheet_160906.pdf

progress in envelope tracking circuits for reducing power dissipation (which extends lifetime), as well as performance improvements via heterogeneous integration with other device technologies.[37] Basic materials and device developments (e.g., low-k dielectrics, silicon-on-insulator wafers, Cu interconnect) are typically slow to be adopted often due to reliability concerns and can take 5-10 years until circuit and product teams learn how to make use of the new technology reliably in their designs. This is currently happening with recent progress in 3D memory technology, with designers learning to leverage the new capability.[38,39] This recent history of progress in advanced electronics has generated ARPA-E's interest in novel power electronic systems enabled by WBG semiconductors to further advance the exciting power electronics technologies developed in previous R&D projects.

C. PROGRAM OBJECTIVES AND TECHNICAL AREAS OF INTEREST

Firstly, this program seeks to fund transformational advances in next-generation advanced converter circuit topologies (building blocks) for use in power electronics systems. These converters should exhibit higher efficiency, more reliability, reduced size and weight, and lower cost relative to the current state of the art. Secondly, this program seeks to fund specific grand technical challenges in application areas covering a broad range of power electronics disciplines, including, but not limited to: electric motor driven systems, automotive (electric and hybrid electric vehicles), electric vehicle chargers, high-performance computing and data centers, power supplies, solar inverters, wind-electric systems, high/medium voltage transmission/distribution, grid applications, power conversion for grid storage, rail/ship propulsion, monolithic power processing, robotic actuators, turbo-lifts, solid-state circuit breakers, power electronics interacting with the grid, and emerging new applications not yet categorized. Consistent with the agency's mission, ARPA-E is seeking clearly disruptive, novel technologies, early in the R&D cycle, and not integration strategies for existing technologies. With the development of these transformational converter circuit topologies and application specific power electronic systems, it will be possible to realize efficiency gains both directly, by inherently more efficient designs, and indirectly, by facilitating higher levels of adoption for fundamentally higher performing materials.

Motivation for the CIRCUITS program is drawn from the fact that the majority of current power converter circuits are optimized for the existing silicon IGBT and MOSFET devices. Simple drop-in substitution of WBG devices for Si devices leads to, in the best-case scenario, an incremental increase in efficiency (or reduction of loss) that does not fully realize the potential of WBG devices.[10] More typical is that the inherently faster switching WBG devices generate very high dv/dt and di/dt transitions that result in voltage overshoots and uncontrolled turn-on caused by package parasitics (e.g. lead inductance), leading to system instability and failure requiring more

[37] Green, Daniel, et al. Heterogeneous Integration for Revolutionary Microwave Circuits at DARPA. *Microwave Journal* (June 2015)
[38] Courtland, Rachel. Intel and Micron Move 3-D NAND into Production. *IEEE Spectrum* (April 2015)
[39] Sugiyama, Yusuke, et al. Application Dependency of 3-D Integrated Hybrid Solid-State Drive System with Through-Silicon Via Technology. *International Conference on Electronic Packaging* (April 2016)

conservative system designs that give up some of what the materials could otherwise offer. Furthermore, at least an order of magnitude greater higher frequency harmonic amplitude generated in WBG converters versus comparable Si systems is often observed, requiring the management of electromagnetic interference (EMI) and noise, which can add to the system size and cost. Clearly new system architectures, converter circuits and control, packaging, and overall optimization are needed for full system realization of the potential for higher breakdown voltages, higher operating frequencies, higher power density, and lower loss WBG technologies.

Significant and non-incremental improvements in converter performance are expected (and achievable), which simultaneously take advantage of advances in WBG semiconductors, and holistically integrate novel converter topologies, digital control, magnetics/passives, thermal management, and semiconductor packaging and interconnect technology. Some example innovative features/concepts that could be incorporated into projects include, but are not limited to and are presented in no particular priority:

- topologies and control methods that combine multiple functions (e.g. rectification and step-down) into one single topology with reconfigurable power flow paths
- innovative utilization of parasitic elements, high density active filters replacing passive filters
- intelligent gate drive for cross talk suppression
- built-in modulation compensators for non-ideal switching
- fully digital control and digital controller algorithms
- high-speed DSP control, gate drive with extreme dv/dt immunity, medium voltage (MV) gate drives
- EMI free circuit topologies, zero-voltage or current switching with minimum magnetics
- power loads with adjustable impedance high frequency circuits and energy storage units
- integrated controls for driving high frequency devices, on-chip low cost stand-alone ultra-fast response time current-voltage sensors, flat magnetics, power-over-fiber based gate drive with comprehensive protection functions
- bi-directional dual gate switches, active transistors capable of VDS > 15 kV and > 1MHz switching
- transformerless inverters for MV power converters for wind turbine generators
- HV small and reliable solid-state transformers (SST), circuit topologies capable of >100 kW of power conversion without magnetics
- 1MW power conversion system utilizing switches at 1 MHz, magnetic materials capable of |Bmax| > 1 Tesla at 1MHz
- combined bi-directional ac-dc charger and dc-dc converter (for automotive environments)
- high efficiency 48V:1V single stage conversion, 3KV DC input solar PV systems
- DC-DC 400V to ≤ 12V converters (for automotive and data center applications)
- low-cost and maintenance free variable frequency drives
- 480Vac 3 phase to ≥ 900Vdc converter, compact sub 2-minute EV charging stations with reduced installation cost
- monolithic WBG power integrated circuits

- fault management and systems that fail in a controlled manner
- power dense actuators
- low-cost and high reliability HVDC circuit breakers
- solid-state breaker circuits with < 1μs response time
- HVDC solid-state switching devices for fast fault isolation in VSC multi-terminal applications
- multi-phase conversion
- multi GW single circuit VSC HVDC transmission
- fully decoupled, intelligent power modules
- high temperature reliable thermal pastes
- shared thermal management solutions, multi-sided cooling
- encapsulation materials that are stable at high operating and cycling temperatures
- new bonding mechanisms for dies and modules
- fiber reinforced plastic foams and elastocaloric cooling
- 3D printed heat exchangers
- active cooling inside packages.

In this FOA two categories of innovation will be considered.

Category 1 is designated for advances in general converter systems and seeks to develop novel circuit topologies, control and drive electronics, packaging techniques, thermal management strategies, and electromagnetic compliance solutions for a universal converter (A/D C, A/D C) that is ≥ 10 kW and ≥ 600 V. It is expected that the proposed solution will meet or exceed the key targets (see section D) in mass-specific and volumetric power densities and efficiency (or Pout/Ploss) at all practical load levels. Furthermore, it is expected that the proposed solutions will be fully contained in a rectangular enclosure and will be designed to operate reliably under a relevant load profile.

Category 2 addresses application specific architectures; solutions are not limited to a single converter box. Submissions must present grand technical challenges metrics that are expected to exceed the state-of-the-art (SOA) in one or more specific areas of power electronics. Areas of interest include but are not limited to: electric motor driven systems, automotive (electric and hybrid electric vehicles), electric vehicle chargers, high-performance computing and data centers, power supplies, solar inverters, wind-electric systems, high/medium voltage transmission/distribution, power electronics enabling smart grid applications, power conversion for grid storage, rail/ship propulsion, monolithic power processing, robotic actuators, multi-axis turbo-lifts, solid-state circuit breakers, and emerging new applications not yet categorized. Whether a concept is transformational or incremental will be judged based on the metrics proposed, energy impact of the solution, and whether the solution has a chance of follow-on funding for early adoption commensurate with the application and specific industry (e.g., product cycles are much shorter and adoption much faster in consumer electronics versus automotive applications).

Research and development projects that address the Technical Performance Targets in Section I.D are expected. ARPA-E will accept applications that provide a well-justified, realistic potential of meeting or exceeding the technical targets. Favorable consideration will be given to applicants who show they can meet or exceed all technical targets within the time frame of the award.

The topics listed below are generally considered outside the scope of this FOA and would only receive modest support under extenuating circumstances:

- WBG drop-in solutions
- New WBG device technology development: It is preferred that teams utilize fully commercial WBG devices or WBG devices that are available as functioning prototypes. Novel WBG device development will be supported only to the extent that the proposed system absolutely requires devices with atypical characteristics
- Novel magnetic material and new capacitor development: limited support will be allowed only if absolutely necessary to the proposed system
- Pure play package and module development
- Submissions with limited path to manufacturability
- Solutions not addressing reliability concerns
- Thermal simulation program development

D. TECHNICAL PERFORMANCE TARGETS

In order to identify and to gauge the potential impact of a novel power electronics topology, metrics for comparison must first be established. Here we use four relevant figures of merit: volumetric power density (output power/volume [kW/L]), mass-specific power density (output power/mass [kW/kg]), relative cost (output power/cost [kW/$]), and relative loss (power loss/output power [W_{loss}/kW]).[40] An important fifth figure of merit for power electronics involves the mitigation of electromagnetic interference (EMI) and noise being produced. Lastly, reliability of the power electronic system supersedes all metrics described above, and thus it should be featured as a key component in every submission.

Technologies able to meet or exceed the "Primary Technical Requirements" and to meet or exceed the majority of the "Secondary Technical Targets" stated below will be considered for award under ***Category 1*** of this FOA.

This FOA is focused around supporting power converter technology research and development projects that are able to address the specific quantitative target performance and cost metrics outlined below. Proposed technology development plans must have well-justified, realistic potential to meet or exceed the stated "Primary Technical Requirements" by the end of the period of performance of the proposed project in order to be considered for award. Proposed technologies will secondarily be evaluated against their well-justified, realistic potential to approach the "Secondary Technical Targets" by the end of the period of performance of the proposed project.

[40] Kolar, J. et al. PWM Converter Power Density Barriers. *IEEJ Trans. IA*, *128* (2008)

The Primary and Secondary Technical Requirements for ***Category 1*** of this FOA are stated in the two tables below.

Category 1: General Converter Systems with Novel Circuit Topologies

PRIMARY TECHNICAL REQUIREMENTS*:*

ID	Category	Target
1.1	Power and Voltage	≥ 10 kW and ≥ 600V
1.2	Efficiency ($Q = P_{out}/P_{loss}$)	≥ 97.5% (Q ≥ 39) @ rated power ≥ 95% (Q ≥ 19) @ 5% rated power
1.3	Power Density	≥ 150 W/in^3 (≥ 9.15 kW/L)
1.4	Specific Power	≥ 5 kW/kg
1.5	EM Compliance	FCC Part 15 B[41]
1.6	Cooling	Passive or Forced Air
1.7	Operation	168-hour continuous basic operation (Relevant load profile defined by applicant)

SECONDARY TECHNICAL REQUIREMENTS*:*

ID	Category	Target
1.8	EMI Filter Volume	≤ 5% of total package volume
1.9	Reliability/Lifetime	Justify MTTF ≥ 2x over SOA
1.10	Relative Cost	≤ 0.05 $/W

The 10kW power level can be realized in laboratory scale and captures the upper limits of residential applications while providing a functional capacity for parallelizing modules to achieve higher-power systems suitable for commercial and industrial applications. This emphasizes the call for proposed modules to be readily scalable beyond 10 kW. Although SOA modules with greater than 97.5% efficiency at full rated power are commercially available in certain applications such as utility-scale PV inverters, the value established in the primary technical requirements is nonetheless transformational when considered in conjunction with the aggressive power density, partial load efficiency, EMI/EMC, and cooling targets. While improving efficiency from 95% to 97.5% may not seem dramatic, this actually requires a 50%

[41] Electronic Code of Federal Regulations. FCC, accessed December 1, 2016, http://www.ecfr.gov/cgi-bin/text-idx?SID=666db16656211e1f5ece8508ad1b59fc&mc=true&node=sp47.1.15.b&rgn=div6

reduction in the losses of the converter, which indicates the usefulness of relative loss (Q) as a metric. For electric transportation, in particular, power density and specific power density are vitally important. Since space under the hood of an automobile comes at a large premium, higher power density designs open a new paradigm for systems engineers that are packaging the complete system. Similarly, heavy power electronics can severely hinder the range of more-electric aircraft and automobiles, which motivates a need for higher specific power density. An important figure of merit for power electronics involves the mitigation of unintentional electromagnetic interference (EMI) noise being produced. EMI considerations have become increasingly important with the adoption of wide bandgap (e.g., GaN and SiC) devices, which can generate very high dv/dt and di/dt transitions owing to their superior switching speeds compared to silicon counterparts. Achieving EMI metrics are key for power electronic systems since EMI is a major source for random system errors, failures, and lockup. Mitigation of EMI adds significant cost to system. Furthermore, it is illegal to ship noncompliant systems. Achieving the primary technical requirements performance metrics in concert will have a transformational impact on a wide variety of applications within the energy sector. Power density of ≥150 W/in^3 (≥9.15 kW/L) provides an impactful benchmark in relation to grand technical challenges in power electronics established through the SunShot program for residential and small commercial PV inverters (≥100 W/in^3) and the 2020 DOE targets for EV inverters (13.4 kW/L).[42,43]

Partial load performance is a critical parameter that seeks to fully utilize the capability of WBG power semiconductors to operate efficiently at light-load conditions. The efficiency of many commercially available power converters decreases sharply below 10% rated power, which has significant energy impact in applications where partial load conditions constitute a substantial portion of operating time, such as VFDs, EV inverters, and PV power electronics in regions with low insolation.[44,45] The additional requirement for utilization of passive or forced air cooling will push innovations in thermal management and packaging that can reduce system-level weight, complexity, and cost in transportation and stationary applications relative to water cooled systems. As for EMI considerations, instead of having to develop large, complex filtering strategies, truly disruptive solutions will minimize or not generate this noise. Filters to attenuate conducted EMI are another important obstacle to power density in all power electronics systems. EMI filters can comprise 15-40% of the inverter's volume. Reduction in filter volume and weight while passing FCC Part 15 B EMI standards constitutes another significant challenge that can potentially be achieved by employing advanced topologies for power electronics systems. Novel topologies with inherently lower EMI will be accepted more readily by industry since this solves an important obstacle that often plagues systems-level integration and can be a bottleneck in successful prototype design.

Applicants in ***Category 1*** must propose at least one potential application area for their converter design. Applicants are also required to convincingly justify why their solution has a pathway to broad impact in at least one ARPA-E mission area, see Section I.A of the FOA. In all Full Applications, a detailed test plan for converter performance and reliability should be provided.

Category 2: Application-Specific Converter Systems

[42] Yuan, G. Developing Next Generation Power Electronics to Enable 100s GW of Solar. SunShot, U.S. DOE (2016)
[43] Vehicle Technologies Office. Advanced Power Electronics and Electric Motors Program. EERE, U.S. DOE (2013)
[44] Anwar, M. et al. Power Dense and Robust Traction Power Inverter for the Second Generation Chevrolet Volt Extended-Range EV. *SAE Int. J. Alt. Power* (2015)
[45] Chen, H. et al. Electrified Automotive Powertrain Architecture Using Composite DC–DC Converters. *IEEE Transactions on Power Electronics* (2017)

In ***Category 2*** this program seeks to fund specific grand technical challenges in application areas covering a broad range of power electronics disciplines, including, but not limited to: electric motor driven systems, automotive (electric and hybrid electric vehicles), electric vehicle chargers, high-performance computing and data centers, power supplies, solar inverters, wind-electric systems, solid-state lighting solutions, high/medium voltage transmission/distribution, grid applications, power conversion for grid storage, rail/ship propulsion, more-electric aerospace, monolithic power processing, robotic actuators, turbo-lifts, solid-state circuit breakers, power electronics interacting with the grid, variable frequency drives, power electronics for telecommunication gear, and emerging new applications not yet categorized.

Effective power converter design requires careful analysis of the fundamental tradeoffs between system-level parameters such as safety, power density, efficiency, reliability, and cost. The relative importance of each of these characteristics depends heavily on the specific application. Figure 2 provides a qualitative example of the compromise between efficiency and power density. Each contour represents the Pareto optimum at a certain maximum operating temperature, where $T_1 < T_2 < T_3$. Because the reliability of the system is in large part a function of temperature, the Mean Time To Failure (MTTF) generally follows the relationship $MTTF_1 > MTTF_2 > MTTF_3$. Applications in which efficiency and reliability are more pertinent than power density (e.g., utility-scale PV inverters) favor the hypothetical converter performance indicated by the square symbol in Figure 2. Alternatively, applications such as automotive PCUs and onboard battery chargers that value high power densities to enable vehicle-level efficiency gains and simplification of cooling systems would benefit most from the performance metrics associated with the circular symbol, assuming reliability can meet or exceed industry standards. Beyond efficiency and power density, a variety of Pareto curves can be generated using combinations of the various system parameters. The overall performance metrics can thus be selected through a multi-objective optimization process, where circuit topologies have been shown to play an important role in defining the system performance limits.[46]

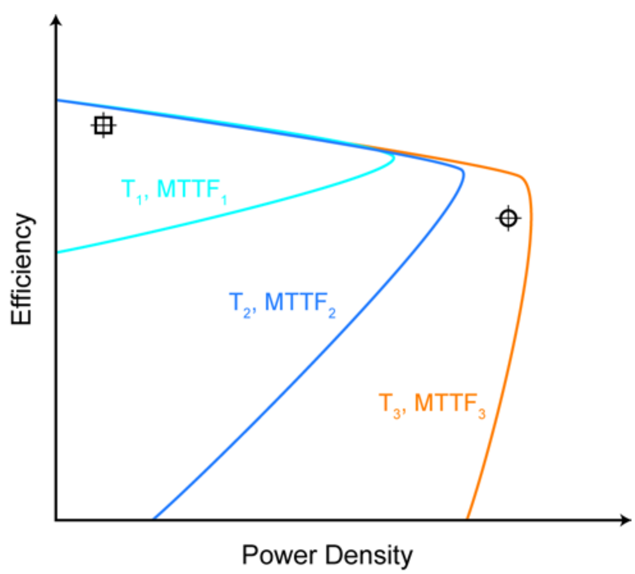

Figure 2. Qualitative illustration of the efficiency-power density Pareto fronts associated with power converter operation. The symbols represent the hypothetical performance characteristics of two distinct converters. T = temperature; MTTF = mean time to failure.

[46] Burkart, R.; Kolar J. W. Component Cost Models for Multi-Objective Optimizations of Switched- Mode Power Converters. *IEEE Energy Conversion Congress and Exposition* (2013)

To accommodate a diverse pool of power electronics applications that have distinct performance and optimization criteria, applicants in ***Category 2*** are responsible for defining and justifying the relevant metrics for their given use case. Applicants must also clearly define the performance of the current commercial SOA technology in their chosen application area and present *quantitative* grand technical challenges targets for their proposed solution with respect to the current SOA using a consistent set of criteria. More details are provided in the table below. Submissions should include discussion of the reciprocity between the specified performance characteristics using a similar framework as the one outlined in the previous paragraph and in Figure 2. Applicants should consider the barriers to commercial adoption in light of these performance tradeoffs (e.g., cost-efficiency, power density-reliability, etc.), with the expectation that early-stage projects will prioritize these tradeoffs differently than projects seeking to be positioned closer to commercialization at the end of the period of performance. Projected impact in at least one of the ARPA-E mission areas must be quantified and well justified. Whether a concept is transformational or incremental will be judged based on the metrics proposed, energy impact of the solution, and whether the solution has a chance of early adoption. Test protocols and procedures for benchmarking the performance of the proposed technology must be described in detail and should be consistent with best practices in the relevant application area.

The following table demonstrates the suggested presentation of technical categories and metrics for applications in ***Category 2***. Applicants should include SOA values and values for the proposed solution for each of the metrics. This table is not meant to be exhaustive, and additional metrics may be added to better contrast the proposed work with the application-specific SOA. Likewise, if a particular category or target in the following table is not relevant for the proposed technology, applicants should justify why it need not be included as a performance criterion.

ID	Category	Target
2.1	Application area	--
2.2	Power module level	Converter/system function [AC/DC, DC/AC, DC/DC, universal
		Power (W) [specify time interval]
		Voltage (V)
		Efficiency (%) and Q (P_{out}/P_{loss}) [peak, rated power, 5% full load, standard weighted]
		Power density (W/in^3 or kW/L); Specific power (kW/kg)
		Relative cost ($/kW)
		Approximate MTTF (h)
		Cooling methodology
		Number of discrete power modules
2.3	Circuit level	Topology/architecture
		Switching methodology
		Switching frequency (kHz)
		Number of discrete drivers
		EMI filter volume
2.4		Transistor type(s) and count

	Component level	Transistor specifications
		Diode type(s) and count
		Diode specifications
		Diode count
		Total semiconductor area (mm^2)
		Module packaging
		Inductor type(s) and count
		Total inductor volume (mm^3)
		Capacitor type(s) and count
		Total capacitor volume (mm^3)
2.5	Benchmarking	Define test protocols and procedures for quantifying converter performance

II. Award Information

A. Award Overview

ARPA-E expects to make approximately $20 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 10-20 awards under this FOA. ARPA-E may, at its discretion, issue one, multiple, or no awards.

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

The period of performance for funding agreements may not exceed 36 months. ARPA-E expects the start date for funding agreements to be October 2017, or as negotiated.

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

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

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

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

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

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

B. ARPA-E FUNDING AGREEMENTS

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[47] Accordingly, ARPA-E has substantial involvement in the direction of every Cooperative Agreement, as described in Section II.C below.

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[48]

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

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

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[47] U.S. Congress, Conference Report to accompany the 21st Century Competitiveness Act of 2007, H. Rpt. 110-289 at 171-172 (Aug. 1, 2007).
[48] The Prime Recipient is the signatory to the funding agreement with ARPA-E.

2. Funding Agreements with FFRDCs/DOE Labs, GOGOs, and Federal Instrumentalities

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

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

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

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

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

3. Technology Investment Agreements

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

A TIA is more flexible than a traditional financial assistance agreement. In using a TIA, ARPA-E may modify standard Government terms and conditions. See 10 C.F.R. § 603.105 for a description of a TIA.

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

C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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

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

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[49] as the lead for a Project Team,[50] or as a member of a Project Team. However, ARPA-E will only award funding to an entity formed by the Applicant.

2. DOMESTIC ENTITIES

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

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

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

3. FOREIGN ENTITIES

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. Foreign entities must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed or to be formed) under the laws of a State or territory of the United States to

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[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.

receive funding. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate. The Applicant may request a waiver of this requirement in the Business Assurances & Disclosures Form, which is submitted with the Full Application and can be found at https://arpa-e-foa.energy.gov/. Please refer to the Business Assurances & Disclosures Form for guidance on the content and form of the request.

4. Consortium Entities

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

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

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

B. Cost Sharing[52]

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

1. Base Cost Share Requirement

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

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement or Grant, 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 when selecting applications for award negotiations (see Section V.B.1 of the FOA).

Under a Technology Investment Agreement, the Prime Recipient must provide at least 50% of the Total Project Cost as cost share. ARPA-E may reduce this minimum cost share requirement, as appropriate.

3. REDUCED COST SHARE REQUIREMENT

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

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

- Small businesses – or consortia of small businesses - will provide 0% cost share from the outset of the project through the first 12 months of the project (hereinafter the "Cost Share Grace Period").[55] If the project is continued beyond the Cost Share Grace Period, then at least 10% of the Total Project Cost (including the costs incurred during the Cost Share Grace Period) will be required as cost share over the remaining period of performance.

- Project Teams where a small business is the lead organization and small businesses perform greater than or equal to 80%, but less than 100%, of the total work under the funding agreement (as measured by the Total Project Cost) the Project Team are entitled to the same cost share reduction and Cost Share Grace Period as provided above to Standalone small businesses or consortia of small businesses.[56]

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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 and FFRDCs.
[54] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.
[55] Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's (SBA) "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (NAICS) (http://www.sba.gov/content/small-business-size-standards). Applicants that are small businesses will be required to certify in the Business Assurances & Disclosures Form that their organization meets the SBA's definition of a small business under at least one NAICS code.

[56] See the information provided in previous footnote.

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

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

- Projects that do not meet any of the above criteria are subject to the minimum cost share requirements described in Sections III.B.1 and III.B.2 of the FOA.

4. Legal Responsibility

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

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

5. Cost Share Allocation

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

6. Cost Share Types and Allowability

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G.1 of the FOA.

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

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

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

In addition, Project Teams may not use independent research and development (IR&D) funds[57] to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment Agreements.

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

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

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

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

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

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

8. COST SHARE VERIFICATION

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

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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

Full Applications are deemed compliant if:

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

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

Replies to Reviewer Comments are deemed compliant if:

- The Applicant successfully uploads its response to ARPA-E eXCHANGE by the deadline stated in the FOA; and
- The Replies to Reviewer Comments comply with the content and form requirements of Section IV.E of the FOA.

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

2. RESPONSIVENESS CRITERIA

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

- Submissions that fall outside the technical parameters specified in this FOA.

- Submissions that have been submitted in response to other currently issued ARPA-E FOAs.
- Submissions that are not scientifically distinct from applications submitted in response to other currently issued ARPA-E FOAs.
- Submissions for basic research aimed solely at discovery and/or fundamental knowledge generation.
- Submissions for large-scale demonstration projects of existing technologies.
- Submissions for proposed technologies that represent incremental improvements to existing technologies.
- Submissions for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).
- Submissions for proposed technologies that are not transformational, as described in Section I.A of the FOA.
- Submissions for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be scalable such that they could be disruptive with sufficient technical progress.
- Submissions that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.
- Submissions that describe a technology but do not propose a R&D plan that allows ARPA-E to evaluate the submission under the applicable merit review criteria provided in Section V.A of the FOA.

3. SUBMISSIONS SPECIFICALLY NOT OF INTEREST

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

- Significant development of component level devices, including power semiconductor devices, magnetics, and capacitors.

4. LIMITATION ON NUMBER OF SUBMISSIONS

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

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

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

2. CONCEPT PAPERS

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

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

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

3. FULL APPLICATIONS

Applicants must submit a Full Application by the deadline stated in the FOA. Applicants will have approximately 31 days from receipt of the Encourage/Discourage notification to prepare and submit a Full Application. Section IV.D of the FOA provides instructions on submitting a Full Application.

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

4. REPLY TO REVIEWER COMMENTS

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

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

5. PRE-SELECTION CLARIFICATIONS AND "DOWN-SELECT" PROCESS

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

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

6. SELECTION FOR AWARD NEGOTIATIONS

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

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

7. MANDATORY WEBINAR

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

B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424 and Budget Justification Workbook/SF-424A. A sample Summary Slide is available on ARPA-E eXCHANGE. Applicants may use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the template for the Summary Slide, the template for the Summary for Public Release, the template for the Reply to Reviewer Comments, and the template for the Business Assurances & Disclosures Form. A sample response to the Business Assurances & Disclosures Form is available on ARPA-E eXCHANGE.

C. CONTENT AND FORM OF CONCEPT PAPERS

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

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

corner of the header of every page. Page numbers must be included in the footer of every page.

- The first paragraph must include the Lead Organization's Name and Location, Principal Investigator's Name, Technical Category, Proposed Funding Requested (Federal and Cost Share), and Project Duration.

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

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

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

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

1. Concept Paper

a. Concept Summary

- Describe the proposed concept with minimal jargon, and explain how it addresses the Program Objectives of the FOA.

b. Innovation and Impact

- Clearly identify the problem to be solved with the proposed technology concept.

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

- Explain the concept's potential to be disruptive compared to existing or emerging technologies.

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

c. Proposed Work

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

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

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

- Describe why the proposed effort is a significant technical challenge and the key technical risks to the project. Does the approach require one or more entirely new technical developments to succeed? How will technical risk be mitigated?

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

- Estimated federal funds requested; total project cost including cost sharing.

d. TEAM ORGANIZATION AND CAPABILITIES

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

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

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

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

D. CONTENT AND FORM OF FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

E. Content and Form of Replies to Reviewer Comments

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

F. Intergovernmental Review

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

G. Funding Restrictions

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

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

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

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

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

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

1. Criteria for Concept Papers

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

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

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

- The feasibility of the proposed work, as justified by appropriate background, theory, simulation, modeling, experimental data, or other sound scientific and engineering practices;
- Sufficiency of technical approach to accomplish the proposed R&D objectives, including why the proposed concept is more appropriate than alternative approaches and how technical risk will be mitigated;
- Clearly defined project outcomes and final deliverables; and
- The demonstrated capabilities of the individuals performing the project, the key capabilities of the organizations comprising the Project Team, the roles and responsibilities of each organization and (if applicable) previous collaborations among team members supporting the proposed project.

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

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

2. CRITERIA FOR FULL APPLICATIONS

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

3. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

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

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

II. **Relevance to ARPA-E Mission Advancement.** Project contributes to one or more of ARPA-E's key statutory goals:
   a. Reduction of US dependence on foreign energy sources;
   b. Stimulation of domestic manufacturing/U.S. Manufacturing Plan;
   c. Reduction of energy-related emissions;
   d. Increase in U.S. energy efficiency;
   e. Enhancement of U.S. economic and energy security; or
   f. Promotion of U.S. advanced energy technologies competitiveness.

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

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

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

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

2. ARPA-E REVIEWERS

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

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

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

3. ARPA-E SUPPORT CONTRACTOR

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

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

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

VI. Award Administration Information

A. Award Notices

1. Rejected Submissions

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

2. Concept Paper Notifications

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

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

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

3. Full Application Notifications

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

B. Administrative and National Policy Requirements

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

C. REPORTING

[TO BE INSERTED BY FOA MODIFICATION IN APRIL 2017]

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

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

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

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

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

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

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

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

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

B. DEBRIEFINGS

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

VIII. Other Information

A. FOAs and FOA Modifications

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

B. Obligation of Public Funds

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

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

C. Requirement for Full And Complete Disclosure

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

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

D. Retention of Submissions

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

E. Marking of Confidential Information

ARPA-E will use data and other information contained in Concept Papers, Full Applications, and Replies to Reviewer Comments strictly for evaluation purposes.

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

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

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

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

F. Title to Subject Inventions

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

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

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

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

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

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

G. <u>Government Rights in Subject Inventions</u>

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

1. GOVERNMENT USE LICENSE

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

2. MARCH-IN RIGHTS

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

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

- The owner or licensee has not taken or is not expected to take effective steps to achieve practical application of the invention within a reasonable time;
- The owner or licensee has not taken action to alleviate health or safety needs in a reasonably satisfactory manner;
- The owner has not met public use requirements specified by Federal statutes in a reasonably satisfactory manner; or
- The U.S. Manufacturing requirement has not been met.

3. U.S. MANUFACTURING REQUIREMENT

ARPA-E requires that awards address whether products embodying or produced through the use of subject inventions (i.e., inventions conceived or first actually reduced to practice under ARPA-E funding agreements) are to be substantially manufactured in the United States by Project Teams and their licensees. The requirement varies depending upon whether an awardee is a small business, University or other type of awardee. The Applicant may request a modification or waiver of the U.S. Manufacturing Requirement.

H. <u>RIGHTS IN TECHNICAL DATA</u>

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

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

- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years in accordance with provisions that will be set forth in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

I. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

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

- Social Security Numbers in any form;
- Place of Birth associated with an individual;
- Date of Birth associated with an individual;
- Mother's maiden name associated with an individual;
- Biometric record associated with an individual;
- Fingerprint;
- Iris scan;
- DNA;
- Medical history information associated with an individual;
- Medical conditions, including history of disease;
- Metric information, e.g. weight, height, blood pressure;
- Criminal history associated with an individual;
- Ratings;
- Disciplinary actions;
- Performance elements and standards (or work expectations) are PII when they are so intertwined with performance appraisals that their disclosure would reveal an individual's performance appraisal;
- Financial information associated with an individual;

- Credit card numbers;
- Bank account numbers; and
- Security clearance history or related information (not including actual clearances held).

J. COMPLIANCE AUDIT REQUIREMENT

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

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

IX. GLOSSARY

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

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

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

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

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

DOE: U.S. Department of Energy.

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

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

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

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

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

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

PI: Principal Investigator.

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

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

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

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

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

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