FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

STRATEGIES FOR WIDE-BANDGAP, INEXPENSIVE TRANSISTORS FOR CONTROLLING HIGH EFFICIENCY SYSTEMS (SWITCHES) (SBIR/STTR)

Announcement Type: Initial Announcement
Funding Opportunity No. DE-FOA-0000941
CFDA Number 81.135

FOA Issue Date:	June 11, 2013
Submission Deadline for Notice of Intent:	5 PM ET, July 8, 2013
Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, July 14, 2013
Submission Deadline for Full Applications:	5 PM ET, July 19, 2013
Submission Deadline for Replies to Reviewer Comments:	5 PM ET, August 26, 2013
Expected Date for Selection Notifications:	Early September
Total Amount to Be Awarded	Approximately $15million, 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 $225,000 and $3.225 million.

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

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

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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 Notices of Intent, 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
Notice of Intent	• Each Applicant must enter the following information into ARPA-E eXCHANGE by the stated deadline: o Project Title; o Lead Organization; o % of effort contributed by the Lead Organization; o The Project Team, including Principal Investigator for the Prime Recipient, Team Members, and Key Participants; and o Abstract – The abstract provided should be 200 words in length, and should provide a truncated explanation of the proposed project.	Mandatory	IV.C	5 PM ET, July 8, 2013
Full Application	• Each Applicant must submit a Technical Volume in Adobe PDF format by the stated deadline. Applicants must use the Technical Volume template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov). The Technical Volume must include the following: o Award Category (0.5 pages max.) o Technical Approach (1 page max.) o R&D Tasks (1 page max.) o R&D Strategy (20 pages max.) o Technology-to-Market Strategy (2 pages max.) o Budget Summary (2 pages max.) o Qualifications, Experience, and Capabilities (3 pages max. for each Personal Qualifications Summary) o Participating Organizations (1 page max.) o Prior Collaboration (1 page max.) o Management Plan (1 page max.) o Multi-Investigator Projects (2 pages max.) o Intellectual Property Strategy (no page limit) • The Technical Volume must be accompanied by: o SF-424 (no page limit, Adobe PDF format); o Budget Justification Workbook/SF424A (no page limit, Microsoft Excel format) o Technical Milestones and Deliverables (10 pages max.) – Applicants must refer to the Technical Milestones and Deliverables - Instructions and Examples document available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov)	Mandatory	IV.D	5 PM ET, July 19, 2013

	o Summary for Public Release (1 page max., Adobe PDF format); o Summary Slide (1 page limit, Microsoft PowerPoint format) – Applicants must use the Summary Slide template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov); o Completed and signed Business Assurances Form (no page limit, Adobe PDF format); and o Completed and signed Other Sources of Funding Disclosure form (no page limit, Adobe PDF format).			
Reply to Reviewer Comments	• Each Applicant may submit a Reply to Reviewer Comments in Adobe PDF format. This submission is optional. Applicants must use the Reply to Reviewer Comments template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov). The Reply may include: o Up to 2 pages of text; and o Up to 1 page of images.	Optional	IV.E	5 PM ET, August 26, 2013

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

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

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

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

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

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

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

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

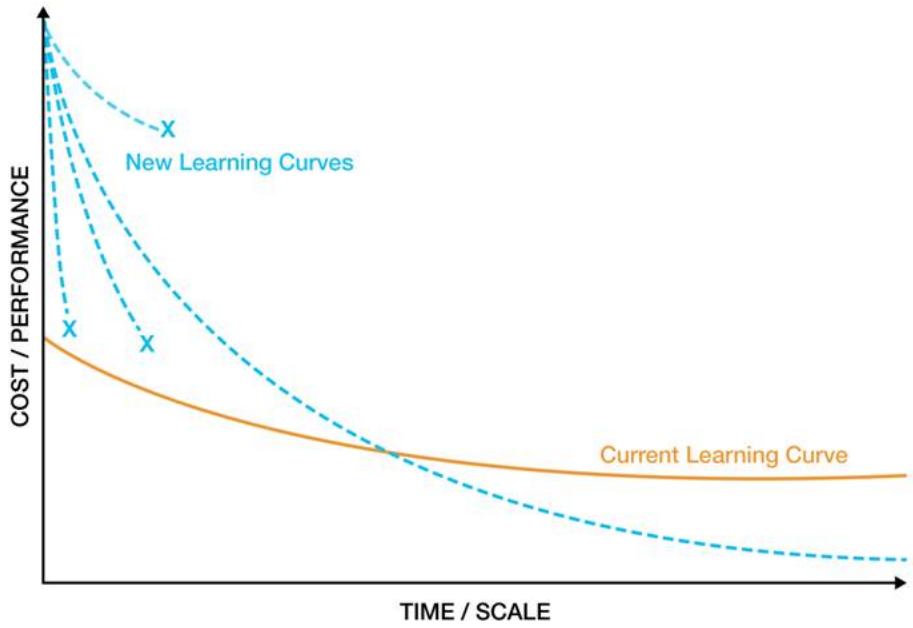

Figure 1: Description of transformational and disruptive technologies in terms of cost, performance, and scale. ARPA-E supports research that establishes new learning curves. A transformational technology becomes disruptive after passing the tipping point.

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

ARPA-E funded technology has the potential to be disruptive in the marketplace. The mere creation of a new learning curve does not ensure market penetration. Rather, the ultimate value of a technology is determined by the marketplace, and impactful technologies ultimately become disruptive – that is, they are widely adopted and displace existing technologies from the marketplace or create entirely new markets. Energy technologies typically become disruptive at maturity rather than close to inception and the maturation of nascent

technologies often require significant incremental development to drives the technology down its natural learning curve to its ultimate equilibrium (see Figure 1 above). Such development might include modification of the technology itself, the means to produce and distribute that technology, or both. Thus, while early incarnations of the automobile were transformational in the sense that they created a fundamentally new learning curve for transportation, they were not disruptive, because of the unreliability and high cost of early automobiles. Continuous, incremental refinement of the technology ultimately led to the Ford Model T: as the first affordable, reliable, mass-produced vehicle, the Model T had a disruptive effect on the transportation market.

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

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

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

B. SBIR/STTR PROGRAM OVERVIEW

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are Government-wide programs authorized under Section 9 of the Small Business Act (15 U.S.C. § 638). The objectives of the SBIR program are to (1) stimulate technological innovation in the private sector, (2) strengthen the role of Small Business Concerns in meeting Federal R&D needs, (3) increase private sector commercialization of innovations derived from Federal R&D activities, (4) foster and encourage participation by socially and economically disadvantaged and women-owned Small Business Concerns, and (5) improve the return on investment from Federally funded research and economic benefits to the Nation. The objective of the STTR program is to stimulate cooperative partnerships of ideas and technologies between Small Business Concerns and partnering Research Institutions through Federally funded R&D activities.[2]

ARPA-E administers a joint SBIR/STTR program in accordance with the Small Business Act and the SBIR and STTR Policy Directives issued by the U.S. Small Business Administration (SBA).[3] ARPA-E provides SBIR/STTR funding in three phases (Phase I, Phase II, and Phase IIS).

C. TECHNICAL PROGRAM OVERVIEW

This program seeks to fund transformational advances in wide bandgap (WBG) materials, device fabrication, and device architectures. The goal of this program is to enable the development of high voltage (1200V+), high current (100A) 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 have promise to reduce the barriers to ubiquitous deployment of low-loss WBG power semiconductor devices in stationary and transportation energy applications.

D. BACKGROUND

Electricity accounted for 40% of primary energy consumption in the United States in 2011.[4] Power electronics are projected to play a significant and growing role in the delivery of this electricity. It has been estimated that as much as 80% of electricity could pass through power

[2] Research Institutions include FFRDCs, nonprofit educational institutions, and other nonprofit research organizations owned and operated exclusively for scientific purposes. Eligible Research Institutions must maintain a place of business in the United States, operate primarily in the United States, or make a significant contribution to the U.S. economy through the payment of taxes or use of American products, materials, or labor.

[3] *See* 77 Fed. Reg. 46806 (Aug. 6, 2012); 77 Fed. Reg. 46855 (Aug. 6, 2012).

[4] U.S. Energy Information Administration, *Annual Energy Review 2011* (Washington, DC: U.S. Department of Energy, 2012), http://www.eia.gov/totalenergy/data/annual/index.cfm

electronics between generation and consumption by 2030.[5] (30% of electrical energy passes through power electronics converters today.) Technical advances in power electronics promise enormous energy efficiency gains throughout the United States economy.[6] Examples of these potential benefits include:

Motor Drives: Electric motors account for over 38% of U.S. electricity consumption.[7] Replacing on/off control or throttling valves with variable frequency drives in industrial pumps and HVAC systems would result in energy savings of up to 65%.[8] Their widespread adoption, enabled by low cost high performance power electronics could yield up to a 20% reduction in U.S. electricity consumption.[9,10]

Automotive: The electrification of vehicles could substantially increase transportation energy efficiency, reduce U.S. oil imports, and mitigate greenhouse gas (GHG) emissions.[11] High costs have thus far prevented these vehicles from gaining widespread adoption. While batteries are the dominant factor in powertrain cost, the limitations of current power electronic systems for both battery charging and traction drive inverters also play an important role. Advances in power electronics promise to substantially reduce the weight and additional cost of the electrification of vehicles.[12]

Electric Power Generation: Power converters are required to connect solar photovoltaics and wind turbines to the electric grid.[13] Advances in power electronics have potential to reduce inverter losses by over 50% while also enabling reductions in cost, weight, and volume.[14] These advances could accelerate the adoption of these new sources of generation, with their commensurate reductions in emissions.

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[5] 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)

[6] "SiC and GaN electronics: Where, when and how big?" *Compound Semiconductor*, July 27, 2012, http://www.compoundsemiconductor.net/csc/features-details.php?cat=features&id=19735293

[7] P. Waide and C. Brunner, "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems." (Paris, France: International Energy Agency, 2011), http://www.iea.org/publications/freepublications/publication/EE_for_ElectricSystems.pdf

[8] Consortium for Energy Efficiency, *Motor Efficiency, Selection, and Management: A Guidebook for Efficiency Programs* (Boston, MA: Consortium for Energy Efficiency, 2011), http://library.cee1.org/sites/default/files/library/9322/CEEMotorGuidebook_2.pdf

[9] M. A. Briere, "GaN on Si Based Power Devices: An Opportunity to Significantly Impact Global Energy Consumption," Paper presented at CS MANTECH Conference, Portland, OR, May 2010, http://www.csmantech.org/Digests/2010/Papers/13.1.066.pdf

[10] M. Lowe, R. Golini, and G. Gereffi, "U.S. Adoption of High-Efficiency Motors and Drives: Lessons Learned," (Center on Globalization, Governance and Competitiveness, Duke University, 2010), http://www.cggc.duke.edu/pdfs/CGGC-Motor_and_Drives_Report_Feb_25_2010.pdf

[11] Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Program, *DOE Vehicle Technologies Multi-Year Program Plan 2011-2015* (Washington, DC: U.S. Department of Energy, 2010), http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/vt_mypp_2011-2015.pdf

[12] Experian Automotive, "Hybrid vehicle market share grew by 41 percent in 2012," news release, April 22, 2013, http://press.experian.com/United-States/Press-Release/experian-automotive-hybrid-vehicle-market-share-grew-by-41-percent-in-2012.aspx

[13] Office of Energy Efficiency and Renewable Energy, Sunshot Initiative, "Sunshot Vision Study," February 2012. (Washington, D.C.: U.S. Department of Energy), http://www1.eere.energy.gov/solar/pdfs/47927.pdf

[14] H Zhang and LM Tolbert , "Efficiency Impact of Silicon Carbide Power Electronics for Modern Wind Turbine Full Scale Frequency Converter," *IEEE Transactions on Industrial Electronics* 58, no. 1 (2011): 21-28, doi: 10.1109/TIE.2010.2048292

Electric Power Transmission: Congestion of electric transmission networks and the challenges associated with variable power generation (wind and solar) can be mitigated with embedded power electronics-based power flow controllers.

Achieving high power conversion efficiency in these systems requires low-loss power semiconductor switches. Today's incumbent power semiconductor switch technology is silicon (Si) based MOSFETs, IGBTs and thyristors. Silicon power semiconductor devices have several important limitations:

(1) High Losses: The relatively low silicon bandgap (1.1 eV) and low critical electric field (30 V/µm) require high voltage devices to have substantial thickness. The large thickness translates to devices with high resistance and associated conduction losses.
(2) Low Switching Frequency: Silicon high voltage power MOSFETs require large die areas to keep conduction losses low. Resulting high gate capacitance and gate charge produce large peak currents and losses at high switching frequencies. Silicon IGBTs have smaller die than MOSFETs due to utilization of minority carriers and conductivity modulation, but the relatively long lifetime of minority carriers reduces the useful switching frequency range of IGBTs.
(3) Poor High-Temperature Performance: The relatively low silicon bandgap also contributes to high intrinsic carrier concentrations in silicon-based devices, resulting in high leakage current at elevated temperatures. Temperature variation of the bipolar gain in IGBTs amplifies the leakage and limits the maximum junction temperature of many IGBTs to 125 °C.

New opportunities for higher efficiency have emerged with the development of wide bandgap (WBG) power semiconductor devices. Table 1 compares several different WBG device materials relative to Si. WBG semiconductor-based devices are capable of low-loss operation at high voltages (> 1 kV to tens of kV), high frequencies (tens of kHz to tens of GHz), and high temperatures (>150^{o}C). Power converters based on WBG devices can achieve both higher efficiency and higher gravimetric and volumetric power conversion densities. For example, in a recent demonstration, a 2kW motor driven by high frequency GaN devices resulted in an increase in efficiency of over 2% at full load and 8% at low load relative to the same motor being driven by Si IGBTs.[15]

[15] Y-F. Wu et al., "High-Frequency, GaN Diode-Free Motor Drive Inverter with Pure Sine Wave Output," *Power Transmission Engineering*, October 2012, 40-43, http://www.powertransmission.com/issues/1012/motor_drive_inverter.pdf

Table 1: Power Semiconductor Material Properties[16,17,18]

		Si	4H-SiC	GaN (2 DEG)	GaN (Bulk)	Diamond
Bandgap	**Eg (eV)**	1.1	3.26	3.39	3.39	5.45
Electron Concentration	**n_i (cm^{-3})**	1.5×10^{10}	8.2×10^{-9}	1.9×10^{-10}	1.9×10^{-10}	1.6×10^{-27}
Electron Mobility (low)	**μ_n ($cm^2/V\ s$)**	1350	700	1000	500	1900
Electron Mobility (high)	**μ_n ($cm^2/V\ s$)**	1450	950	2000	1200	4000
Electron Saturation Velocity	**v_{sat} (10^7cm/s)**	1	2	2.5	2.5	2.7
Breakdown Electric Field	**E_{br} (MV/cm)**	0.3	3	3.3	3.3	5.6
Thermal Conductivity	**k (W/cm °K)**	1.5	4.9	1.3	2.3	20
Maximum Operating Temperature	**T_{max} (°C)**	175	500	650	650	700

Substantial technical progress has been made on WBG-based power switches over the past decade. Substantial investments from the Department of Defense[19] and several DOE offices, including the Advanced Manufacturing Office,[20] the Office of Electricity Delivery and Energy Reliability,[21] and the Vehicle Technologies Program,[22] 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

[16] U.K. Mishra, L. Shen, T.E. Kazior, and Y-F. Wu, "GaN-Based RF Power Devices and Amplifiers," *Proceedings of the IEEE* 96, no. 3 (2008): 287-305, doi: 10.1109/JPROC.2007.911060

[17] F. Morancho, "State of the art and trends in power semiconductor devices for optimized power management," Presentation at 40th Anniversary Meeting of LAAS-CNRS, Toulouse, France, October 2008, http://www.laas.fr/files/LAAS/40ans_LAAS-CNRS_A5-Morancho.pdf

[18] C. Mion et al., "Accurate dependence of gallium nitride thermal conductivity on dislocation density," *Applied Physics Letters* 89, 092123 (2006), doi: 10.1063/1.2335972

[19] "DARPA Sets Tough Goals For The Wide-Bandgap Community," *Compound Semiconductor*, November 8, 2002, http://compoundsemiconductor.net/csc/features-details.php?id=11332

[20] 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), http://www1.eere.energy.gov/manufacturing/rd/pdfs/wbg_2012_workshop_summary_report.pdf

[21] Office of Electricity Delivery and Energy Reliability, *Power Electronics Research and Development Program Plan,* April 2011 (Washington, DC: U.S. Department of Energy), http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/OE_Power_Electronics_Program_Plan_April_2011.pdf

[22] 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), http://www1.eere.energy.gov/vehiclesandfuels/pdfs/program/vt_mypp_2011-2015.pdf

devices and demonstrate their efficacy in system demonstrations.[23] The ADEPT program focused on transformational power electronics advances in a wide range of high efficiency power conversion systems. These include fully-integrated, chip-scale power converters for dimmable solid state lighting drivers and computer power supplies; package integrated power converters for automotive and industrial applications; and medium voltage converters for utility grid applications. Several ADEPT projects focused on WBG devices. For example, several program teams have recently demonstrated enhancement-mode (normally off), 600V+ GaN-on-Si High Electron Mobility Transistors (HEMTs).[24] SiC diodes with 10 kV rating and IGBT's with blocking voltages exceeding 15kV have also been demonstrated.[25,26]

SiC and GaN have also made important commercial progress over the past decade with 1200 V SiC devices[27] and 600 V GaN[28] devices now qualified and commercially available. However, SiC and GaN device technology remains relatively immature relative to Si and currently carry a substantial cost premium, limiting their widespread adoption.[29] The state of technology is such that many of the largest opportunities for increased energy efficiency and reduced energy-related emissions exist in extremely cost conscious industries, including markets for railway traction drives, automotive applications, and industrial motors.[30,31,32] Cost for an equivalent functional performance remains a major barrier to the widespread adoption of WBG devices, despite opportunities for superior performance (including reductions in system costs).[33] WBG devices will have to approach functional cost parity with Si power devices to gain widespread adoption.

In addition to high cost, most WBG discrete devices demonstrated to date have had relatively low current ratings. Traction, industrial, and grid applications advantage devices with high

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[23] "Agile Delivery of Electrical Power Technologies," ARPA-E, U.S. Department of Energy, accessed June 2, 2013, http://arpa-e.energy.gov/?q=arpa-e-programs/adept

[24] B. Hughes et al., "GaN HFET switching characteristics at 350V/20A and synchronous boost converter performance at 1MHz." Paper presented at Twenty-Seventh Annual IEEE Applied Power Electronics Conference and Exposition (APEC), Orlando, FL, February 2012, doi: 10.1109/APEC.2012.6166174

[25] "High Temperature SiC Bare Die," GeneSiC Semiconductor, accessed June 6, 2013, http://www.genesicsemi.com/index.php/hit-sic/baredie

[26] S.H. Ryu et al., "15 kV IGBTs in 4H-SiC," *Materials Science Forum* 740-742 (2013): 954-957, doi: 10.4028/www.scientific.net/MSF.740-742.954

[27] Cree, "Cree Announces Volume Production of Second-Generation SiC MOSFET, Bringing Significant Cost Savings to Power-Conversion Systems," news release, March 13, 2013, http://www.cree.com/news-and-events/cree-news/press-releases/2013/march/2nd-gen-mosfet

[28] Transphorm Inc., "Transphorm Releases First JEDEC-Qualified 600 Volt GaN on Silicon Power Devices," news release, March 14, 2013, http://www.transphormusa.com/news/transphorm-releases-first-jedec-qualified-600-volt-gan-silicon-power-devices

[29] 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, http://www.apec-conf.org/images/PDF/2013/Industry_Sessions/is1.4.2.pdf

[30] "Railway Inverter with Hybrid SiC Power Module," *Power Electronics Europe*, October 5, 2012

[31] M. Lowe, R. Golini, and G. Gereffi, "U.S. Adoption of High-Efficiency Motors and Drives: Lessons Learned," (Center on Globalization, Governance and Competitiveness, Duke University, 2010), http://www.cggc.duke.edu/pdfs/CGGC-Motor_and_Drives_Report_Feb_25_2010.pdf

[32] K. Boutros, R. Chu, and B. Hughes, "GaN power electronics for automotive application." Paper presented at 2012 IEEE Energytech, Cleveland, OH, May 2012, doi: 10.1109/EnergyTech.2012.6304646

[33] 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, http://www.apec-conf.org/images/PDF/2013/Industry_Sessions/is1.4.2.pdf

current ratings (>100 A) because implementation of low amperage devices in parallel increases power system complexity and cost.

As viable devices become commercially available and device maturity increases, WBG device costs are expected to fall over the next several years.[34,35] Device manufacturers are continuing to reduce defect densities (enabling higher device yields) and also have plans to migrate to larger substrates as demand increases. However, despite these improvements, existing WBG fabrication processes and device architectures make it difficult for the devices to achieve functional cost parity with silicon-based devices as well as achieve the high current ratings that are needed in high power applications. In particular, lateral high electron mobility transistor (HEMT) devices (the dominant GaN device architecture today) suffer from relatively low current densities relative to die size, which limits the ability to cost effectively scale lateral device topologies to high current ratings.

E. TECHNICAL PROGRAM OBJECTIVES

This program seeks to fund transformational advances in WBG materials, device fabrication and device architectures. The goal of this program is to enable the development of high voltage (1200V+), high current (100A) power semiconductor devices that, upon reaching scale, have the potential to reach functional cost parity with silicon power semiconductor devices on a $/A basis, while also offering breakthrough relative performance (low losses, high switching frequencies, and high temperature operation). These transformational technologies promise to reduce the barriers to ubiquitous deployment of low-loss wide bandgap power semiconductor devices in stationary and transportation applications.

Recent research results indicate that new materials advances, device architectures, and device fabrication processes could substantially accelerate progress towards WBG devices that achieve both higher current ratings and functional cost parity with silicon-based devices, thus gaining ubiquitous deployment.[36,37,38] These approaches have, as of yet, received relatively little attention from industry and the research community since they are perceived to be technically unproven and high risk.

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[34] 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, http://www.apec-conf.org/images/PDF/2013/Industry_Sessions/is1.4.2.pdf

[35] "GaN power electronics market may top $1bn in a few years," *Semiconductor Today*, March 8, 2012, http://www.semiconductor-today.com/news_items/2012/MAR/YOLE_080312.html

[36] S. Chowdhury et al., "CAVET on Bulk GaN Substrates Achieved With MBE-Regrown AlGaN/GaN Layers to Suppress Dispersion," *IEEE Electron Device Letters* 33, no. 1 (2012): 41-43, doi: 10.1109/LED.2011.2173456

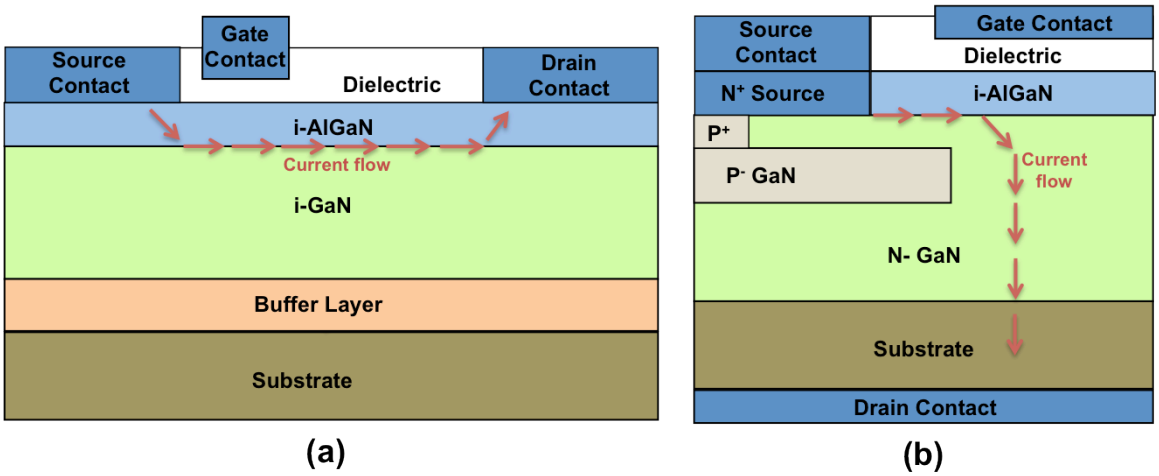
[37] R. Yeluri et al., "Demonstration of Low ON-Resistance CAVETS with Ammonia MBE Grown Active p-GaN Layer as the Current Blocking Layer for High Power Applications." Paper presented at The Pacific Rim Meeting on Electrochemical and Solid-State Science, Honolulu, HI, October 2012, http://ma.ecsdl.org/content/MA2012-02/30/2531.short

[38] I.C. Kizilyalli et al. "Vertical Devices In Bulk GaN Drive Diode Performance To Near-Theoretical Limits," *How2Power Today*, March 2013, http://www.how2power.com/newsletters/1303/articles/H2PToday1303_design_Avogy.pdf

Vertical device architectures for GaN power semiconductor transistors, for example, could substantially reduce cost and increase current densities (relative to die size). The dominant GaN device architecture today is the High Electron Mobility Transistor (HEMT) heterostructure depicted in Figure 1(a). For this structure, the source, drain, and gate terminals are all located on the surface of the device. Current flows laterally through a 2D Electron Gas (2DEG) that forms at the GaN/AlGaN heterojunction interface. The high electron mobility that is achieved in a 2DEG makes this device architecture appealing. GaN based HEMTs are particularly attractive as the free-carrier concentration in the 2DEG channel is formed by strain induced and spontaneous polarization, shifting the Fermi-level above the conduction band without the presence of mobility limiting extrinsic dopants. This device architecture has also received substantial attention due to the ability to be fabricated on GaN layers deposited heteroepitaxially on low cost silicon substrates.

However, the lateral GaN HEMT device architecture has two key limitations. First, since all three contacts are located on the top surface of the devices, high-voltage devices require careful management of electric field profiles in the lateral dimension between contacts, particularly in high voltage applications. Substantial gate/drain lateral spacing must be maintained to allow for high breakdown voltages. This requirement substantially reduces the effective current density (relative to die size) that can be achieved in these devices and also leads to a reduction in effective current density as breakdown voltage is increased. Low current densities drive down the number of die that can be fabricated on each wafer as voltage ratings increase, thus increasing the cost for a given amperage rating. Second, thermal management is complicated by the fact that all current flow is confined to a relatively thin portion of the device near the top surface. Joule heating related to device losses must be dissipated across the thickness of the substrate, motivating research into advanced wafer thinning or complicated thermal spreading approaches to device assembly.

Figure 1: GaN Device Structures



In contrast, vertical GaN device architectures as illustrated in Figure 1(b), could overcome these limitations.[39] Vertical device structures for GaN have, thus far, received relatively little attention in the research community but have been recognized as a necessary eventual device architecture for use in high power automotive applications.[40,41,42,43,44,45,46] In these devices, high electric fields occur between contacts on the bottom and top of the structure in the vertical dimension only. As with vertical FET and IGBT technologies in silicon, it is expected that vertical devices will be able to achieve higher effective current densities and will enable improved thermal management.[47] Recent demonstrations of high-voltage vertical structure GaN devices appear very promising.[48,49,50]

Among wide bandgap semiconductors, SiC devices today already demonstrate[51] a vertical device structure, and dies with >100A current ratings are now commercially available.[52] However, SiC device design remains challenging, die sizes are relatively large, and prices remain high. Most commercial devices today are majority carrier devices. While these devices switch substantially faster than silicon-based devices and are starting to gain commercial traction, they currently operate far from the theoretical limits for SiC. This is primarily due to a high density of interface states close to the conduction band edge introduced by the silicon dioxide gate in these devices.[53] These interface states lead to degradation of channel mobility by an order of

[39] M. Su et al., "Challenges in the Automotive Application of GaN Power Switching Devices," Paper presented at CS MANTECH Conference, Boston, MA, April 2012, http://gaasmantech.com/Digests/2012/papers/10a.3.077.pdf
[40] T. Uesugi and T. Kachi, "Which are the Future GaN Power Devices for Automotive Applications, Lateral Structures or Vertical Structures?," Paper presented at CS MANTECH Conference, Palm Springs, CA, May 2011, http://gaasmantech.com/Digests/2011/papers/12b.2.pdf
[41] Tsutomu Uesugi and Tetsu Kachi, "GaN Power Switching Devices for Automotive Applications," Paper presented at CS MANTECH Conference, Tampa, FL, May 2009, http://mantech.org/Digests/2009/2009 Papers/2.1.pdf
[42] M.Kanechika et al., "A Vertical Insulated Gate AlGaN/GaN Heterojunction Field-Effect Transistor," *Japanese Journal of Applied Physics* 46, no. 21 (2007): L503-L505, doi: 10.1143/JJAP.46.L503
[43] M. Sugimoto et al., Nitride semiconductor device and method of manufacturing the same. U.S. Patent Application 20110316049, filed March 2, 2009, published December 29, 2011
[44] H. Ueda et al., "Wide-Bandgap Semiconductor Devices for Automobile Applications," Paper presented at CS MANTECH Conference, Vancouver, BC, Canada, April 2006, http://csmantech.pairserver.com/Digests/2006/2006 Digests/3A.pdf
[45] T. Kachi, D. Kikuta, and T. Uesugi, "GaN power device and reliability for automotive applications," Paper presented at 2012 IEEE International Reliability Physics Symposium (IRPS), Anaheim, CA, April 2012, doi: 10.1109/IRPS.2012.6241815
[46] M. Su et al., "Challenges in the Automotive Application of GaN Power Switching Devices," Paper presented at the CS MANTECH Conference, Boston, MA, April 2012, http://gaasmantech.com/Digests/2012/papers/10a.3.077.pdf
[47] S. Sze, *Physics of Semiconductor Devices* (Wiley-Interscience, 1981)
[48] I.C. Kizilyalli et al. "Vertical Devices In Bulk GaN Drive Diode Performance To Near-Theoretical Limits," *How2Power Today*, March 2013, http://www.how2power.com/newsletters/1303/articles/H2PToday1303_design_Avogy.pdf
[49] A. Bindra "As Applications Emerge, SiC Technology Charts A Growth Path," *How2Power Today*, May 2013, http://www.how2power.com/newsletters/1305/H2PowerToday1305_Semiconductors.pdf
[50] R.P. Tompkins et al., "GaN Power Schottky Diodes," Paper presented at the 2012 Electrochemical Society Meeting, Seattle, WA, May 2012, http://ma.ecsdl.org/content/MA2012-01/22/909.full.pdf
[51] L. Cheng, et al., "High Performance, Large-Area, 1600 V / 150 A, 4H-SiC DMOSFET for Robust High-Power and High-Temperature Applications," Paper presented at the 25th International Symposium on Power Semiconductor Devices and ICs (ISPSD 2013) Kanazawa, Japan, May 2013.
[52] Cree, "Cree Announces Volume Production of Second-Generation SiC MOSFET, Bringing Significant Cost Savings to Power-Conversion Systems," news release, March 13, 2013, http://www.cree.com/news-and-events/cree-news/press-releases/2013/march/2nd-gen-mosfet
[53] R. Singh, "High Power SiC Pin Rectifiers" in *SiC Materials And Devices,* eds. M.Shur et al. (Singapore: World Scientific Publishing, 2006).

magnitude[54] and decreased device switching speed. Also, the high electric field near the gate oxide in SiC MOSFETs prevents the devices from taking full advantage of the breakdown field strength of SiC. [55]

There have also been efforts on minority carrier SiC devices. While few minority carrier devices with insulated gates have been attempted, they would also likely suffer from degraded mobility due to interface states. Some silicon carbide minority carrier devices avoid using an insulated gate, but still require large charge injection[56] at turn-on and suffer from reduced current gain at elevated temperatures.[57] High current density operation in minority carrier devices can also be hindered by forward voltage degradation due to stacking fault defects,[58] which reduce the useful area of a die and may result in non-uniform current flow, localized overheating, and premature failures.

Finally, SiC device designs today typically require a high temperature anneal during implant activation.[59] This process step requires fabrication equipment that is not generally available in legacy (silicon) device fabrication facilities, increasing device fabrication costs. Device designs compatible entirely with silicon fabrication facilities (except epitaxial growth) could be an important pathway to lower costs.

There are several classes of unmet technological and scientific challenges that need to be solved in order to achieve high voltage, high current WBG devices, on a pathway to widespread adoption in power switches:

> (1) Device Structures and Fabrication Processes: New WBG device structures that are compatible with higher current ratings and low cost are needed. Device architectures that allow higher current densities such as vertical GaN devices appear promising. Fabrication process improvements are also needed. Improved approaches to fabricating buried p-type layers or improvements in metal-semiconductor contact formation on N-polar or semi-polar GaN crystal orientations are also needed. Device designs that are compatible with lower cost fabrications processes, such as those that allow the use of legacy silicon device fabrication facilities could also be transformational and disruptive. Device structures minimizing mask count could also reduce costs. Device structures that reduce thermal management challenges could also be important. Finally, high voltage

[54] A.F. Frazzetto et al., "Limiting mechanism of inversion channel mobility in Al-implanted lateral 4H-SiC metal-oxide semiconductor field-effect transistors," *Applied Physics Letters* 99, 072117 (2011). doi: 10.1063/1.3627186
[55] A. Agarwal,et al., "Temperature dependence of Fowler-Nordheim current in 6H-and 4H-SiC MOS capacitors," *IEEE Electron Device Letters* 18, no. 12 (1997): 592-594, doi: 10.1109/55.644081
[56] GeneSiC Semiconductor, GA06JT12-247 Datasheet, accessed June 6, 2013, http://www.genesicsemi.com/images/products_sic/sjt/GA06JT12-247.pdf
[57] R. Singh, et al., "1200 V-class 4H-SiC "Super" Junction Transistors with Current Gains of 88 and Ultra-fast Switching capability," *Materials Science Forum* 717 (2012): 1127-1130
[58] R.E. Stahlbush et al., "Effect of Stacking Faults Originating from Half Loop Arrays on Electrical Behavior of 10 kV 4H-SiC PiN Diodes," *Materials Science Forum* 387, (2012): 717-720, http://www.scientific.net/MSF.717-720.387
[59] S. Haney et al., "The effects of implant activation anneal on the effective inversion layer mobility of 4H-SiC MOSFETs," *Journal of Electronic Materials* 37, no. 5 (2008): 666-671, http://link.springer.com/article/10.1007/s11664-007-0310-6

devices require relatively thick films of high quality (low defect) WBG materials. New approaches to growing WBG materials at higher speeds are needed.[60,61]

(2) Substrates: In support of the device architectures above, new substrate crystal growth, wafering and fabrication processes may be needed. Bulk GaN substrates with high quality material, required for many vertical device concepts, are currently limited to small sizes and are very costly to produce. High quality bulk GaN substrates with low defect densities are critical, as it has been shown that thermal conductivity of GaN is strongly dependent on material quality.[62] New chemistries for epitaxial growth or substrate refining techniques appear to have substantial potential.[63] Many substrates have small domain structure unsuitable for large area power devices. New approaches to fabricating bulk substrates could be an important pathway to achieving high current low cost devices.[64,65,66,67] The III-V photovoltaics community has also recently demonstrated how epitaxial liftoff and substrate reuse can be used to achieve substantially lower cost devices despite high substrate costs.[68] These same concepts could find application in wide bandgap power semiconductor devices.

F. TECHNICAL AREAS OF INTEREST

This program is focused on supporting the development of breakthrough solutions in WBG power electronics that enable high single die current ratings and the potential to reach functional cost parity with silicon-based power semiconductor devices. Research and development projects that address the Primary and Secondary Technical Targets described in Section I.G of the FOA are encouraged. ARPA-E is most interested in applications that provide a well-justified, realistic potential of meeting or exceeding all of the Primary and Secondary Technical Targets.

The following technical areas are of particular interest to this FOA:

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[60] T. Rana, "Elimination of silicon gas phase nucleation using tetrafluorosilane (SiF4) precursor for high quality thick silicon carbide (SiC) homoepitaxy." *physica status solidi* (a) 209, no. 12 (2012): 2455-2462. http://onlinelibrary.wiley.com/doi/10.1002/pssa.201228319/full

[61] D. Miller, "Gallium Nitride Epitaxy by a Novel Hybrid VPE Technique,"(PhD diss., Stanford University, 2011)

[62] C. Mion et al., "Accurate dependence of gallium nitride thermal conductivity on dislocation density," *Applied Physics Letters* 89, 092123 (2006), doi: 10.1063/1.2335972

[63] T. Rana, et al.,"Comparison of 4H Silicon Carbide Epitaxial Growths at Various Growth Pressures Using Dicholorosilane and Silane Gases." *Materials Science Forum* 717 (2012): 117-120, http://www.scientific.net/MSF.717-720.117.

[64] T.J. Baker et al. "Technique for the Growth of Planar Semi-Polar Gallium Nitride." U.S. Patent 8,128,756, filed February 1, 2010, and issued March 6, 2012

[65] J. Bai et al. "Efficient Reduction of Defects in (1120) Non-Polar and (1122) Semi-polar GaN Grown on Nanorod Templates," *Applied Physics Letters* 102 (2013): 101906, doi: 10.1063/1.4795619

[66] D. Ehrentraut, E. Meissner, and M. Bockowski. eds., *Technology of Gallium Nitride Crystal Growth* (Springer-Verlag Berlin Heidelberg, 2010)

[67] Q. Sun and J. Han, "Heteroepitaxy of Nonpolar and Semipolar GaN." In *GaN and ZnO-based Materials and Devices*, ed. S. Pearton (Springer-Verlag Berlin Heidelberg, 2012), 1-27, http://www.springer.com/cda/content/document/cda_downloaddocument/9783642235207-c1.pdf?SGWID=0-0-45-1268759-p174192762

[68] K. Lee et al, "Reuse of GaAs Substrates for Epitaxial Lift-off by Employing Protection Layers," *Journal of Applied Physics* 111 (2012): 033527, doi: 10.1063/1.3684555

- Wide bandgap power semiconductor devices utilizing novel fabrication processes or device structures not previously supported by ARPA-E, other governmental agencies or previously developed for commercial application; such technologies might include vertical GaN device structures, approaches to device fabrication that are compatible with substrate re-use (i.e. device liftoff), and novel structures compatible with far lower cost fabrication processes and high die current ratings. New approaches to fast, high quality thick film epitaxial growth that enables rapid fabrication of high voltage devices are also of interest.

- Investigation of technologies with the potential to enable extremely low cost and highly scalable free standing wide bandgap substrate fabrication. Such technologies might include, but are not limited to, new GaN, ZnO, SnO_2, sapphire, or other wide bandgap substrate growth techniques. Approaches that enable larger substrate sizes and substantially reduced defect densities are required. These may include advances in new chemistries for epitaxial growth or substrate refining techniques.

Researchers who might be working on sub-system materials or component level innovations are highly encouraged to partner with device designers and manufacturers as a means of evaluating device level functionality resulting from breakthroughs in the proposed effort.

G. TECHNICAL PERFORMANCE TARGETS

This FOA focuses on devices with high voltage and current ratings based on WBG semiconductor materials, device fabrication processes, and device architectures that could enable functional cost parity with conventional Si-based switches. The vision for ubiquitous wide bandgap power semiconductor device deployment is based on these devices reaching functional cost parity with today's dominant power semiconductor switch technology in high power applications: Silicon IGBTs. Table 2 lists the Primary Technical Targets for this FOA while Table 3 lists Secondary Technical Targets.

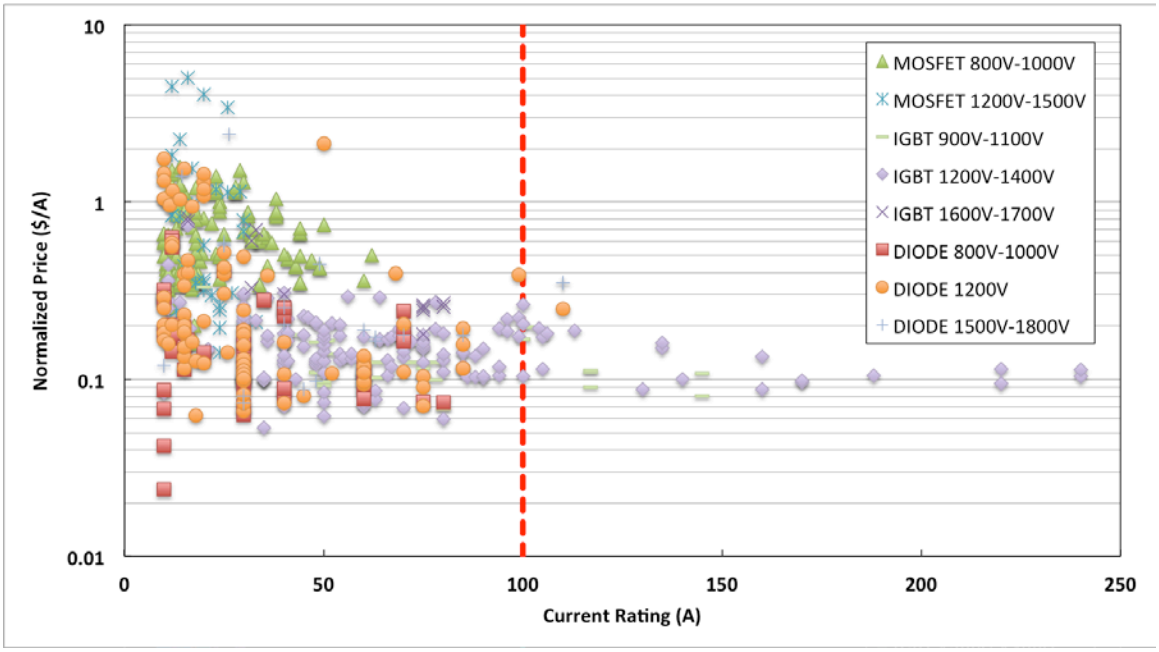
Figure 2 plots the price ($/A) of existing high-voltage silicon power semiconductor devices using data from the electronic components distributor Digi-Key (http://www.digikey.com/).[69] All in stock devices with relevant ratings and pricing information readily available on the Digi-Key website as of late May 2013 are included in the figure. Variability in this plot is associated primarily with different package technologies and the different applications that are targeted by each particular device. This plot indicates that 1200V, 100A devices are typically priced between $0.10/A and $0.20/A today. Si device costs are expected to continue to fall incrementally over the next decade. Based on these data, it is expected that WBG devices

[69] This figure is based on ARPA-E analysis of Digi-Key (http://www.digikey.com/) data. By using data provided by Digi-Key, ARPA-E does not endorse Digi-Key as a vendor, nor does it make any warranty (express or implied) or assume any liability or responsibility for the accuracy, completeness, or usefulness of the data provided by Digi-Key. Applicants may refer to similar data provided by other distributors of electronic components, including but not limited to Newark (www.newark.com) and Mouser (www.mouser.com).

achieving costs of below $0.10/A (Primary Technical Target 1.1) would represent a functionally cost equivalent technology, with potential advantages of WBG devices.

The superior performance of WBG devices, relative to the Si switches they are replacing, will allow them to gain adoption in many applications before reaching functional cost parity. However, truly widespread adoption in high power, conservative, cost conscious applications such as industrial motors and automotive applications may require functional cost parity for the devices themselves.

Figure 2: Si Power Semiconductor Prices



With regard to Primary Technical Target 1.1, all Applicants must justify how the proposed technology holds promise to meet this FOA's $0.10/A device cost target. While ARPA-E understands that some Applicants may not have access to sophisticated power semiconductor device manufacturing cost modeling tools, ARPA-E expects that all Applicants will make a strong effort to present an adequate justification. The cost target is intended to be a forward looking consideration of device costs, including packaging, assuming successful technology development and subsequent scaling of manufacturing for ubiquitous deployment. Applicants should describe all assumptions related to the scale that would be needed to achieve $0.10/A. In addition, ARPA-E expects selected Applicants will revise cost-models through the course of the proposed effort, reflecting technical advances achieved during the work and demonstrating how increased scientific understanding provides a pathway to ultimately achieving cost targets in the program.

Primary Technical Targets 1.2 – 1.6 describe device characteristics that should be demonstrated experimentally in a single device by the end of the project period. These targets are consistent with the characteristics of devices that are required in high power applications, including many

motor drive systems and in electric vehicles. Primary Technical Target 1.7 is a requirement to demonstrate that devices designed and fabricated under this program are suitable for high frequency switching applications. Appropriate thermal management of devices will be critical to successfully meeting this technical target. Devices achieving all of the primary technical targets will be relevant for a wide range of applications.

TABLE 2: PRIMARY TECHNICAL TARGETS

ID	Category	Value
1.1	Discrete Device Cost (Packaged)	<= $0.10 /A
1.2	Drain-Source Breakdown Voltage	>= 1200 V (V_{DSS} @ T_C = 25°C and V_{GS} = 0)
1.3	Continuous Drain Current Rating (Single Die)	>= 100 A (I_D @ T_C = 25°C and V_{GS} <= 20 V)
1.4	Operating Junction Temperature	-55 °C to 150 °C
1.5	I_{off}/ I_{on} Ratio	> 10^6
1.6	V_{th} (not applicable to diodes)	> 2 V @ I_D = 5 mA
1.7	Dynamic Performance	Project must demonstrate device driving a hard switched boost (PFC) converter at f >= 40 kHz, Vout = 800 V, Imax = 50 A.

The Secondary Technical Targets listed in Table 3 are based on the desire to achieve low losses and high switching speeds. The targets are based on an assumed cooling limit of approximately 200W/cm^2 under 40kHz hard switching with a 50% duty cycle. This cooling limit is consistent with the capabilities of commonly used low cost packaging technologies.

TABLE 3: SECONDARY TECHNICAL TARGETS

ID	Category	Value
2.1	Specific R_{DSON}	< 3 mΩ·cm^2 @ V_{GS} = 15 V
2.2	Switching Loss E_{ON}+E_{OFF}	< .5 mJ @ 800 V and 50 A

Applicants proposing sub-system materials or component level innovations should specify and explain the materials and/or component level technical targets that they believe must be achieved to achieve the device-related Primary Technical Requirements specified in Tables 2 & 3.

ARPA-E will not consider selecting projects for award that do not clearly demonstrate realistic, well justified potential to meet or exceed the Primary Technical Requirements.

H. APPLICATIONS SPECIFICALLY NOT OF INTEREST

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

- Applications that fall outside the technical areas and parameters specified in Sections I.F and I.G of the FOA, including but not limited to:
  - Power conversion system demonstrations that are not connected to the development of new semiconductor switch technology.
  - Incremental advances to existing GaN and SiC fabrication processes and/or existing device architectures including lateral GaN HEMT structures.
  - Simulations or computer models of power semiconductor devices which do not include innovation related to any specific device design or fabrication process.

- Applications submitted by entities or organizations other than Small Business Concerns.

- For the STTR program, applications submitted without one Research Institution as a member of the project team.

- Applications that were already submitted to pending ARPA-E FOAs.

- Applications that are not scientifically distinct from applications submitted to pending ARPA-E FOAs.

- Applications for basic research aimed at discovery and fundamental knowledge generation.

- Applications for large-scale demonstration projects of existing technologies.

- Applications for proposed technologies that represent incremental improvements to existing technologies.

- Applications for proposed technologies that are not based on sound scientific principles (e.g., violates a law of thermodynamics).

- Applications that do not address at least one of ARPA-E's Mission Areas (see Section I.A of the FOA).

- Applications for proposed technologies that are not transformational, as described in Section I.A of the FOA and as illustrated in Figure 1 in Section I.A of the FOA.

- Applications for proposed technologies that do not have the potential to become disruptive in nature, as described in Section I.A of the FOA. Technologies must be

scalable such that they could be disruptive with sufficient technical progress (see Figure 1 in Section I.A of the FOA).

- Applications that are not scientifically distinct from existing funded activities supported elsewhere, including within the Department of Energy.
- Applications with clear technology show stoppers that prevent reaching the Primary or Secondary Technical Targets that are not addressed clearly by the applicant.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $15 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 4-8 awards under this FOA. ARPA-E may issue one, multiple, or no awards.

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

Each Full Application must identify the award category under which it is seeking funding (see Section IV.D.1 of the FOA). ARPA-E has established two award categories for this FOA. **A Full Application may not request funding under more than one award category.**

- **Combined Phase I/II Awards** are intended to develop transformational technologies with disruptive commercial potential. Such commercial potential may be evidenced by (1) cost sharing or follow-on funding by private or non-SBIR/STTR sources, or (2) the Small Business Concern's record of successfully commercializing technologies developed under prior SBIR/STTR awards. Combined Phase I/II awards may be funded up to $1,725,000 and have a period of performance up to 36 months (3 years). ARPA-E anticipates making 1-3 awards in this category.

- **Combined Phase I/II/IIS Awards** are similar to Combined Phase I/II awards, but include a "sequential" (i.e., additional) Phase II award, a.k.a. Phase IIS award, to allow the continued development of promising energy technologies. Combined Phase I/II/IIS awards may be funded up to $3,225,000 and may have a period of performance up to 48 months (4 years). ARPA-E anticipates making 3-5 awards in this category.

In evaluating applications for Combined Phase I/II and Combined Phase I/II/IIS awards, ARPA-E reserves the right to fund only Phase I or Phase I and Phase II of a proposed project. Applicants may not apply exclusively for a Phase I award. The maximum award amount for a Phase I award is $225,000.

Although each Full Application must designate a single award category, the Applicant may request both SBIR and STTR funding for that category. A Small Business Concern may request both SBIR and STTR funding under the same award category if:

- The Small Business Concern is partnered with a Research Institution;

- The Small Business Concern performs at least 66.7% of the work in Phase I and at least 50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost;

- The partnering Research Institution performs 30-33.3% of the work in Phase I and 30-50% of the work in Phase II and/or Phase IIS (as applicable), as measured by the Total Project Cost; and

- The Principal Investigator (PI) is employed by the Small Business Concern. If the PI is employed by the Research Institution, the application will be considered only under the STTR program.

B. ARPA-E FUNDING AGREEMENTS

ARPA-E uses Cooperative Agreements to provide financial and other support to Prime Recipients.[70]

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.

Phase I of Combined Phase I/II awards and Combined Phase I/II/IIS awards will be made on a fixed-obligation basis. Phase II and Phase IIS of Combined Phase I/II awards and Combined Phase I/II/IIS awards will be made on a reimbursement basis.

ARPA-E encourages Prime Recipients to review the Model Cooperative Agreement for SBIR/STTR Awards, which is available at http://arpa-e.energy.gov/?q=arpa-e-site-page/sbir-sttr-guidance.

C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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

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

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

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

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

- ARPA-E reviews reimbursement requests for compliance with applicable Federal cost principles and Prime Recipients' cost share obligations for Phase II and Phase IIS of Combined Phase I/II awards and Combined Phase I/II/IIS awards. Upon request, Prime Recipients are required to provide additional information and documentation to support claimed expenditures. Prime Recipients are required to comply with agency-specific and programmatic requirements. Please refer to Section VI.B.3-4 of the FOA for guidance on proof of cost share commitment and cost share reporting.

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

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. SBIR

SBA rules and guidelines regarding SBIR/STTR program eligibility govern eligibility to apply to this FOA. For information on program eligibility, please refer to SBA's "Guide to SBIR/ STTR Program Eligibility" (http://sbir.gov/sites/default/files/elig_size_compliance_guide.pdf).

A Small Business Concern[71] may apply as a Standalone Applicant[72] or as the lead organization for a Project Team.[73] If applying as the lead organization, the Small Business Concern must perform at least 66.7% of the work under the award in Phase I and at least 50% of the work under the award in Phase II and Phase IIS (as applicable), as measured by the Total Project Cost.[74]

2. STTR

SBA rules and guidelines regarding SBIR/STTR program eligibility govern eligibility to apply to this FOA. For information on program eligibility, please refer to SBA's "Guide to SBIR/ STTR Program Eligibility" (http://sbir.gov/sites/default/files/elig_size_compliance_guide.pdf).

A Small Business Concern may apply only as the lead organization for a Project Team. The Small Business Concern must perform at least 40% of the work under the award in Phase I, Phase II, and/or Phase IIS (as applicable), as measured by the Total Project Cost. A single Research Institution must perform at least 30% of the work under the award in Phase I, Phase II, and/or Phase IIS (as applicable), as measured by the Total Project Cost. Please refer to Section III.B.1 of the FOA for guidance on Research Institutions' participation in STTR projects.

For information on eligibility as a Small Business Concern, please refer to SBA's Guide to "SBIR/ STTR Program Eligibility" (http://sbir.gov/sites/default/files/elig_size_compliance_guide.pdf)

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[71] A Small Business Concern is a for-profit entity that: (1) maintains a place of business located in the United States; (2) operates primarily within the United States or makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor; (3) is an individual proprietorship, partnership, corporation, limited liability company, joint venture, association, trust, or cooperative; and (4) meets the size eligibility requirements set forth in 13 C.F.R. § 121.702. Where the entity is formed as a joint venture, there can be no more than 49% participation by foreign business entities in the joint venture.

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

[73] 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.

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

B. ELIGIBLE SUBRECIPIENTS

1. RESEARCH INSTITUTIONS

A Research Institution[75] may apply only as a member of a Project Team (i.e., as a Subrecipient to a Small Business Concern). In STTR projects, a single Research Institution must perform at least 30%, but no more than 60%, of the work under the award in Phase I, Phase II, and/or Phase IIS (as applicable), as measured by the Total Project Cost.

2. OTHER PROJECT TEAM MEMBERS

The following entities are eligible to apply for SBIR/STTR funding as a member of a Project Team (i.e., as a Subrecipient to a Small Business Concern):

- For-profit entities, including Small Business Concerns;
- Nonprofits other than Research Institutions;[76]
- Non-DOE/NNSA Government-Owned, Government Operated laboratories (GOGOs);
- State, local, and tribal government entities; and
- Foreign entities.[77]

In SBIR projects, Project Team members other than the lead organization, including but not limited to Research Institutions, may collectively perform no more than 33.3% of the work under the award in Phase I and no more than 50% of the work under the award in Phase II and/or Phase IIS (as applicable). This includes efforts performed by Research Institutions.

In STTR projects, Project Team members (other than the lead organization and the partnering Research Institution) may collectively perform no more than 30% of work under the award in Phase I, Phase II, and/or Phase IIS (as applicable).

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[75] Research Institutions include FFRDCs, nonprofit educational institutions, and other nonprofit research organizations owned and operated exclusively for scientific purposes. Eligible Research Institutions must maintain a place of business in the United States, operate primarily in the United States, or make a significant contribution to the U.S. economy through the payment of taxes or use of American products, materials, or labor.

[76] 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 Subrecipient.

[77] All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (see Section IV.G.6 of the FOA). However, the Applicant may request a waiver of this requirement in the Business Assurances Form submitted with the Full Application.

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

C. ELIGIBLE PRINCIPAL INVESTIGATORS

1. SBIR

For the duration of the award, the PI for the proposed project (or, if multiple PIs, at least one PI) must be employed by, and perform at least 50% of his or her work for, the Prime Recipient. The Contracting Officer may waive this requirement or approve the substitution of the PI.

For projects with multiple PIs, at least one PI must meet the primary employment requirement. That PI will serve as the contact PI for the Project Team.

2. STTR

For the duration of the award, the PI for the proposed project (or, if multiple PIs, at least one PI) must be employed by, and perform at least 50% his or her work for, with the Prime Recipient or the partnering Research Institution. The Contracting Officer may waive this requirement or approve the substitution of the PI.

For projects with multiple PIs, at least one PI must meet the primary employment requirement. That PI will serve as the contact PI for the Project Team.

D. COST SHARING[78]

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

1. BASE COST SHARE REQUIREMENT

Prime Recipients are not required to contribute cost share during Phase I of a SBIR/STTR award. The Prime Recipient must contribute at least 20% of the Total Project Cost[79] as cost share for work performed during Phase II and Phase IIS of a SBIR/STTR award, as applicable.

[78] Please refer to Section VI.B.3-4 of the FOA for guidance on cost share payments and reporting.
[79] The Total Project Cost is the sum of the Prime Recipient share and the Federal Government share of total allowable costs. The Federal Government share generally includes costs incurred by GOGOs, FFRDCs, and GOCOs.

2. LEGAL RESPONSIBILITY

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

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

3. 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.

4. COST SHARE TYPES AND ALLOWABILITY

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

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

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

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

- Proceeds from the prospective sale of an asset of an activity;

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

- Expenditures that were reimbursed under a separate Federal program.

In addition, Project Teams may not use independent research and development (IR&D) funds[80] to meet their cost share obligations under cooperative agreements.

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

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

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

5. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

6. COST SHARE VERIFICATION

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

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

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

E. OTHER

1. COMPLIANT CRITERIA

Notices of Intent are deemed compliant if:

- The Applicant entered all required information and clicked the "Create Submission" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

ARPA-E will not review or consider noncompliant Notices of Intent, including Notices of Intent submitted through other means, Notices of Intent submitted after the applicable deadline, and incomplete Notices of Intent. A Notice of Intent 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 Notice of Intent;
- The Applicant and proposed Project Team members meet the eligibility requirements in Section III.A – III.C of the FOA;
- The Full Application complies with the content and form requirements in Section IV.D of the FOA; and
- The Applicant entered all required information, successfully uploaded all required documents, and clicked the "Submit" button in ARPA-E eXCHANGE by the deadline stated in the FOA.

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

Replies to Reviewer Comments are deemed compliant if:

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

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments, including Replies submitted through other means and Replies submitted after the applicable deadline.

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

2. RESPONSIVENESS CRITERIA

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

3. LIMITATION ON NUMBER OF APPLICATIONS

Applicants may submit up to two (2) applications to this FOA, provided that each application is scientifically distinct.

Applicants eligible to apply to this FOA are restricted from applying to ARPA-E FOA DE-FOA-0000942, Strategies for Wide-bandgap, Inexpensive Transistors for Controlling High Efficiency Systems (SWITCHES).

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN SBA COMPANY REGISTRY

The first step in applying to this FOA is registering in the U.S. Small Business Administration (SBA) Company Registry (http://sbir.gov/registration). Upon completing registration, Applicants will receive a unique small business Control ID and Registration Certificate in Adobe PDF format, which may be used at any participating SBIR and STTR agencies. Applicants that have previously registered in the SBA Company Registry need not register again.

Applicants that are sole proprietors and do not have an Employer Identification Number may use social security numbers for purposes of registering in the SBA Company Registry. Applicants that not possess a Dun and Bradstreet Data Universal Numbering System (DUNS) number may also use their social security number in the SBA Company Registry. Applicants selected for award negotiations will be required to obtain a DUNS number (See Section VI.B.1 of the FOA).

Applicants must submit their Registration Certificate in ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov) as part of their Full Application (see Section IV.D.7 of the FOA).

2. REGISTRATION IN ARPA-E eXCHANGE

Prior to submitting any application materials to ARPA-E, Applicants must register 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).

3. NOTICES OF INTENT

Applicants must submit a Notice of Intent by the deadline stated in the FOA. Applicants should submit a Notice of Intent early in the FOA process. Failure to comply with this requirement will render the Applicant's Full Application ineligible for consideration. Section IV.C of the FOA provides instructions on submitting a Notice of Intent.

ARPA-E performs a preliminary review of Notices of Intent to determine whether they are compliant, as described in Section III.E of the FOA. ARPA-E will not review or consider noncompliant Notices of Intent.

4. FULL APPLICATIONS

Applicants must submit a Full Application by the deadline stated in the FOA. 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.E of the FOA. ARPA-E reviews only compliant and responsive Full Applications.

5. 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.E of the FOA. ARPA-E will review and consider compliant Replies only. ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

6. "DOWN-SELECT" PROCESS

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

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

7. 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.1 and V.B.1 of the FOA. ARPA-E may select or not select a Full Application for award negotiations. ARPA-E may also postpone a final selection determination on one or more Full Applications until a later date, subject to

availability of funds and other factors. ARPA-E will enter into award negotiations only with selected Applicants.

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

8. MANDATORY WEBINAR

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

B. APPLICATION FORMS

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

C. CONTENT OF NOTICES OF INTENT

The Notice of Intent is mandatory (i.e. in order to submit a Full Application, a compliant Notice of Intent must have been submitted). Each Applicant must enter the following information into ARPA-E eXCHANGE by the deadline stated in the FOA:

- Project Title;
- Abstract – The abstract provided should be 200 words in length, and should provide a truncated explanation of the proposed project.
- Lead Organization;
- % of effort contributed by the Lead Organization; and
- The Project Team, including:
  - The Principal Investigator for the Prime Recipient;

- Team Members (i.e., Subrecipients); and
- Key Participants (i.e., individuals who contribute in a substantive, measurable way to the execution of the proposed project).

Each Notice of Intent should be limited to a single concept or technology. Unrelated concepts and technologies should not be consolidated into a single Notice of Intent.

ARPA-E will not review or consider noncompliant Notices of Intent (see Section III.E of the FOA).

ARPA-E eXCHANGE automatically assigns a Control Number upon the submission of a compliant Notice of Intent. 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. The Control Number must be included in the header of the Full Application and optional Reply to Reviewer Comments.

D. CONTENT AND FORM OF FULL APPLICATIONS

Full Applications must conform to the following requirements:

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

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

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

Component	Required Format	Description and Information
Technical Volume	PDF	The centerpiece of the Full Application. Provides a detailed description of the proposed R&D project and Project Team. Applicants must complete the Technical Volume template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).

SF-424	PDF	Application for Federal Assistance (https://arpa-e-foa.energy.gov)
Budget Justification Workbook/SF-424A	XLS	Budget Information – Non-Construction Programs (https://arpa-e-foa.energy.gov)
Technical Milestones and Deliverables	PDF	Applicants must use the Technical Milestones and Deliverables – Instructions and Examples available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov) for the Technical Milestones and Deliverables.
Summary for Public Release	PDF	Short summary of the proposed R&D project. Intended for public release. Applicants must complete the Summary for Public Release template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov).
Summary Slide	PPT	A four-panel project slide summarizing different aspects of the proposed R&D project. Applicants must complete the Summary Slide template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov). A sample Summary Slide is also available on ARPA-E eXCHANGE.
SBA Company Registration Certificate	PDF	Registration Certificate generated upon completion of registration in the SBA Company Registry (http://sbir.gov/registration).
Certification for Applicants Majority-Owned by Multiple Venture Capital Operating Companies, Hedge Funds, or Private Equity Firms	PDF	Requires SBIR Applicants that are majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms to self-identify and verify registration as such in the SBA Company Registry (http://sbir.gov/registration).
Business Assurances Form	PDF	Requires the Applicant to acknowledge eligibility with SBIR/STTR program requirements, disclose potential improprieties and potential conflicts of interest within the Project Team, and provide written assurance of its cost share commitment. If the Applicant is a FFRDC, requires the Applicant to provide written authorization from the cognizant Federal agency and, if a DOE/NNSA FFRDC, a Field Work Proposal. Allows the Applicant to request a modification or waiver of the Performance of Work in the United States requirement and/or the U.S. manufacturing requirement. This form is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov. A sample response to the Business Assurances Form is also available on ARPA-E eXCHANGE.
Other Sources of Funding Disclosure form	PDF	Requires the PI to describe the additionality and risks associated with the proposed project, disclose financial assistance from Federal entities, disclose funding from non-Federal entities for related work, and provide letters or other communications from private investors explaining why they decided not to fund the proposed R&D project. This form is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov. A sample response to the Other Sources of Funding Disclosure Form is also available on ARPA-E eXCHANGE.

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

1. FIRST COMPONENT: TECHNICAL VOLUME

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

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

SECTION	PAGE LIMIT	DESCRIPTION
Award Category	0.5 pages max.	• Identify the Award Category: Combined Phase I/II or Combined Phase I/II/IIS. See Section II.A of the FOA. • State the type of funding being sought: SBIR, STTR, or both SBIR and STTR. See Section II.A of the FOA.
Technical Approach	1 page max.	• Provide a concise summary of the proposed R&D project. The summary should be written for a technically literate, but non-specialist, audience.
R&D Tasks	1 page max.	• Describe succinctly: o The purpose of the proposed R&D project, o The underlying hypothesis(es)/technical concept(s) guiding the approach, and o A list of the tasks the research team will undertake and accomplish to achieve this purpose.
R&D Strategy	20 pages max.	• Applicants are <u>required</u> to describe each of the following aspects of their proposal. Applicants should present supporting references, data, calculations, estimates, and/or projections to justify each set of claims, explicitly stating any variables and assumptions. o <u>Innovation and Impact</u> – Describe and justify: ▪ the performance of current state-of-the-art technology solutions in the application area addressed, ▪ how the proposed solution is a departure from currently available technology and differs from others under investigation in the field, ▪ the performance of the proposed solution, and the extent to which it represents a significant advance relative to the state of the art, ▪ the impact of the proposed solution on system-level performance metrics, including justification for any adverse effects on system performance, ▪ how the anticipated cost of the proposed solution compares with currently available technology, and the extent to which the solution can achieve a disruptive cost-performance learning curve relative to the state of the art ▪ the extent to which the technology benefits, if realized, will translate into substantial impact on one or more ARPA-E mission areas. o <u>Feasibility</u> – Describe and justify: ▪ the feasibility of the proposed technology solution, and capability of achieving the cost and performance targets at scale (i.e. large-volume/high-throughput scenario) o <u>Performance Team</u> – Describe succinctly: ▪ the members of the proposed research team, and ▪ why the proposed team is uniquely qualified to carry out the proposed research. Synopses of past research

		accomplishments are insufficient to demonstrate that a team is "uniquely qualified." Applicants are required to identify the unique combination of training and experience that make the proposed team uniquely qualified to successfully execute the proposed project. Preference will be given to multidisciplinary teams where different Project Team members complement each other and have expertise in different aspects of the technology.
Technology-to-Market Strategy	2 pages max.	• ARPA-E supports energy technology R&D projects for a limited period of time at critical high-risk points in the technology development cycle. ARPA-E technologies *are not required* to achieve commercial deployment by the end of the project period; however, funded projects must be on a reasonable path toward making substantive impact on ARPA-E's mission areas through commercial adoption and eventual wide-scale market deployment. If known, please describe: o How the proposed technology is expected to transition from the lab to deployment and adoption. Please include: description of the expected product, potential near-term and long-term markets of entry, likely commercialization approach (startup, license, etc.), specific organizations expected to be involved in the transition of the technology (partners, customers, etc.), expected timeline for commercialization; o Manufacturing and scalability risks associated with technology; o Resource needs for the next phase of development that follows the end of the ARPA-E project; and o Why the proposed research is not being pursued by industry today.
Budget Summary	2 pages max.	• Applicants are required to provide a two-page budget summary, broken down by milestones. The summaries must conform to the following guidelines: o The budget summary should be clearly associated with the milestones outlined as part of the Technical R&D Plan and reflect quarterly progress on the proposed project. o All major equipment purchases must be included in the budget summary. For equipment acquired as part of the proposed R&D project, state the proposed disposition of the equipment after the project's completion. Specifically, state if the useful life of the equipment will correlate with its authorized purpose under the proposed project. o If costs are less than would normally be expected due to large amounts of previous R&D work done by one or more members of the research team, please describe and explain accordingly. o Applicants are required to estimate the potential materials and manufacturing costs of the proposed technology to justify the technology's potential to approach, meet, or exceed the cost targets given in each FOA. In making these estimations, Applicants must describe the manufacturing approaches that will most likely scale up the proposed technologies.

Qualifications, Experience, and Capabilities	For each PQS, 3 pages max.	• Applicants are required to provide a Personal Qualification Summary (PQS) for the PI and each Key Participant.[81] Each PQS is limited to 3 pages maximum. Curriculum vitae will not be considered. Each PQS must include: o Education/training, o Employment history, o Awards and honors, o Up to 10 peer-reviewed publications specifically related to the proposed R&D project, o Up to 10 other peer-reviewed publications demonstrating capabilities in the broad field, and o Up to 10 non-peer reviewed publications and patents demonstrating capabilities in the broad field.
Participating Organizations	1 page max.	• Describe succinctly why each proposed organization is qualified to accomplish their portion of the proposed R&D project. Please describe the Project Team's unique qualifications, expertise, equipment, or facilities that will facilitate the successful completion of the proposed project.
Prior Collaboration	1 page max.	• Describe succinctly: o Any prior projects, programs, and initiatives on which the Project Team has collaborated; o The roles of each Project Team member in the project, program, or initiative; o Whether the project, program, or initiative was ultimately successful; and o Any management, intellectual property, or other issues that arose within the Project Team and how they were resolved.
Management Plan	1 page max.	• An effective management plan is essential to ensure continuous effective communication between performance members. Describe succinctly: o The roles of each Project Team member; o Any critical handoffs/interdependencies between Project Team members; o The technical (i.e., decision-making based on technical understanding of the problem) and management (i.e., monitoring different elements of the project and technology to ensure that it is well-integrated) aspects of the Management Plan and the role of the PI.
Multi-Investigator Projects	2 pages max.	• Roles of Participants: For multi-organizational or multi-investigator projects, describe succinctly: o The roles and the work to be performed by each PI and Key Participant; o Business agreements between the Applicant and each PI and Key Participant; and o How the various efforts will be integrated and managed. • Multiple PIs: Standalone Applicants and Project Teams are required to disclose if the project will include multiple PIs. If multiple PIs will be designated, identify the Contact PI/Project Coordinator, and provide a "Coordination and Management Plan" that describes the organization

[81] A Key Participant is any individual who would contribute in a substantive, measurable way to the execution of the proposed project.

		structure of the project as it pertains to the designation of multiple PIs. This plan should include: o Process for making decisions on scientific/technical direction; o Publication arrangements; o Intellectual property issues; o Communication plans; o Procedures for resolving conflicts; and o PIs' roles and administrative, technical, and scientific responsibilities for the project.
Intellectual Property Strategy	No page limit	• Describe specifically: o Existing intellectual property that will be used to develop the new intellectual property; o New intellectual property and data that will be created as part of this effort; o How the intellectual property strategy will increase the probability that the proposed transformational technology will reach the market and widely penetrate the installed base; and o The plan for disposition/ownership of the intellectual property, including intellectual property agreements or memorandums of understanding between Project Team members.

2. SECOND COMPONENT: SF-424

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

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

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

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

- Each Project Team should submit only one SF-424 (i.e., a Subrecipient should not submit a separate SF-424).

- Assume a project start date of January 1, 2014, or as negotiated.

- The list of certifications and assurances in Block 21 can be found at http://energy.gov/management/downloads/certifications-and-assurances-use-sf-424.

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

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

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

Subrecipient information must be submitted as follows:

- Each Subrecipient incurring greater than or equal to 10% of the Total Project Cost must complete a separate Budget Justification workbook to justify its proposed budget. These worksheets must be inserted as additional sheets within in the Prime Recipient's Budget Justification.

- Subrecipients incurring less than 10% of the Total Project Cost are not required to complete a separate Budget Justification workbook. However, such Subrecipients are required to provide supporting documentation to justify their proposed budgets. At a minimum, the supporting documentation must show which tasks/subtasks are being performed, the purpose/need for the effort, and a sufficient basis for the estimated costs.

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

- Applicants may request funds under the appropriate object class category tabs as long as the item and amount requested are necessary to perform the proposed work, meet all the criteria for allowability under the applicable Federal cost principles, and are not prohibited by the funding restrictions described herein.

- If Patent costs are requested, they must be included in the Applicant's proposed budget (see Section IV.G.3 of the FOA for more information on Patent Costs).

- For pricing purposes, assume a project start date of January 1, 2014, or as negotiated.

- For more information, please refer to the ARPA-E Budget Justification Guidance document at https://arpa-e-foa.energy.gov.

4. FOURTH COMPONENT: TECHNICAL MILESTONES AND DELIVERABLES

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

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

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

5. FIFTH COMPONENT: SUMMARY FOR PUBLIC RELEASE

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

6. SIXTH COMPONENT: SUMMARY SLIDE

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

The Summary Slide template requires the following information:

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

7. SEVENTH COMPONENT: SBA REGISTRATION CERTIFICATE

Applicants are required to provide a copy of the SBA Registration Certificate generated in the SBA Company Registry (http://sbir.gov/registration) in Adobe PDF format (see Section IV.A.1 of the FOA). Applicants that have previously registered in the SBA Company Registry may submit a copy their existing Registration Certificate.

8. EIGHTH COMPONENT: CERTIFICATION FOR APPLICANTS MAJORITY-OWNED BY MULTIPLE VENTURE CAPITAL OPERATING COMPANIES, HEDGE FUNDS, AND PRIVATE EQUITY FIRMS

Applicants that are majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms are required to complete the Certification for Applicants Majority-Owned by Multiple Venture Capital Operating Companies, Hedge Funds, and Private Equity Funds. The certification must be submitted in Adobe PDF format. This form is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov.

In the Certification for Applicants Majority-Owned by Multiple Venture Capital Operating Companies, Hedge Funds, and Private Equity Funds, the Applicant is required to self-identify as an entity that falls into one of those categories, verify its ownership status, and verify that it has registered in the SBA Company Registry (http://sbir.gov/registration) as such an entity.

Applicants that are not majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms are not required to complete this certification.

9. NINTH COMPONENT: BUSINESS ASSURANCES FORM

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

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

- Acknowledge that it has reviewed SBA's eligibility requirements for the SBIR and STTR programs and that it anticipates that it will be able to certify eligibility to participate in ARPA-E's SBIR/STTR program at the time of award;
- Disclose potential improprieties, such as convictions for fraud and export control violations;
- Disclose potential conflicts of interest within the Project Team; and
- Provide written assurance of its cost share commitment; and
- If the Project Team will include a FFRDC, submit written authorization from the cognizant Federal agency; and
- If the Project Team will include a DOE/NNSA FFRDC, submit a Field Work Proposal.

In addition, the Applicant may:

- Request authorization to perform some work overseas;
- Request a modification or waiver of the U.S. Manufacturing requirement.

10. TENTH COMPONENT: OTHER SOURCES OF FUNDING DISCLOSURE FORM

ARPA-E is required by statute to "accelerat[e] transformational technological advances in areas that industry is by itself not likely to undertake because of technical and financial uncertainty."[82] In accordance with its statutory mandate, ARPA-E requires the PI to complete

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

the Other Sources of Funding Disclosure Form and submit it with the Full Application. The form must be submitted in Adobe PDF format. The Other Sources of Funding Disclosure Form is available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov). A sample response to the Other Sources of Funding Disclosure Form is also available on ARPA-E eXCHANGE.

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

- Describe the additionality and risks associated with the proposed R&D project;
- Disclose whether the PI or any Co-PI(s) have submitted the same application to any Federal or non-Federal entities;
- Disclose whether the PI or any Co-PI(s) have submitted any applications for related work to any Federal or non-Federal entities within the last 24 months;
- Disclose all financial assistance from any Federal entity that the PI or any Co-PI(s) is currently receiving or has received within the last 5 years;
- Disclose any funding from non-Federal entities for related work that the PI or any Co-PI(s) is currently receiving or has received within the last 5 years; and
- Provide any letters or other communications from private investors explaining why they decided not to fund the proposed R&D project or related work.

E. CONTENT AND FORM OF REPLIES TO REVIEWER COMMENTS

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

Replies to Reviewer Comments must conform to the following requirements:

- The Reply to Reviewer Comments must be submitted in Adobe PDF format.
- The Reply to Reviewer Comments must be written in English.

- All pages must be formatted to fit on 8-1/2 by 11 inch paper with margins not less than one inch on every side. Use Times New Roman typeface, a black font color, and a font size of 12 points or larger (except in figures and tables).

- The Control Number must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page.

ARPA-E will not review or consider noncompliant Replies to Reviewer Comments (see Section III.E of the FOA). ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

Replies to Reviewer Comments must conform to the following content and form requirements, including maximum page lengths, described below. If a Reply to Reviewer Comments is more than three pages in length, ARPA-E will review only the first three pages and disregard any additional pages.

SECTION	PAGE LIMIT	DESCRIPTION
Text	2 pages maximum	• Applicants may respond to one or more reviewer comments or supplement their Full Application.
Images	1 page maximum	• Applicants may provide graphs, charts, or other data to respond to reviewer comments or supplement their Full Application.

F. INTERGOVERNMENTAL REVIEW

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

G. FUNDING RESTRICTIONS

1. ALLOWABLE COSTS

All expenditures must be allowable, allocable, and reasonable in accordance with the applicable Federal cost principles. ARPA-E has listed the Federal cost principles for different categories of Applicants at http://arpa-e.energy.gov/?q=arpa-e-site-page/post-award-guidance-sbir-sttr.

2. PRE-AWARD COSTS

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

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

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

Please refer to the "SBIR/STTR Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/?q=arpa-e-site-page/pre-award-guidance-sbir-sttr) for additional guidance on pre-award costs.

3. PATENT COSTS

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

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

ARPA-E will reimburse up to $30,000 in costs and fees incurred in preparing and filing domestic and foreign patents. The Prime Recipient may request a waiver of the $30,000 cap. The waiver request is subject to review by the ARPA-E Program Director and approval by the Contracting Officer.

4. CONSTRUCTION

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

5. FOREIGN TRAVEL

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

6. PERFORMANCE OF WORK IN THE UNITED STATES

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

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

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

7. PURCHASE OF NEW EQUIPMENT

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

8. LOBBYING

Prime Recipients and Subrecipients may not use any Federal funds to influence or attempt to influence, directly or indirectly, congressional action on any legislative or appropriation matters.[83]

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

[83] 18 U.S.C. § 1913.

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

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). Notices of Intent, 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 Notice of Intent, 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.E.1 of the FOA). The following errors could cause an application to be deemed "incomplete" and thus noncompliant:

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

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

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

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

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

1. CRITERIA FOR FULL APPLICATIONS

Full Applications are evaluated based on the following criteria:

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

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

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

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

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

- The extent to which the Applicant manages risk, by identifying major technical R&D risks and clearly proposes feasible, effective mitigation strategies; and

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

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

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

- The extent to which the PI and Project Team have the skill and expertise needed to successfully execute the project plan, evidenced by prior experience that demonstrates an ability to perform R&D of similar risk and complexity; and

- The extent to which the Applicant has access to the equipment and facilities necessary to accomplish the proposed R&D effort and/or a clear plan to obtain access to necessary equipment and facilities.

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

- The extent to which the Applicant presents a plausible plan to manage people and resources;

- The extent to which the Applicant proposes allocation of appropriate levels of effort and resources to proposed tasks;

- Whether the proposed schedule is reasonable.

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

Impact of the Proposed Technology Relative to State of the Art	30%
Overall Scientific and Technical Merit	30%
Qualifications, Experience, and Capabilities	30%
Sound Management Plan	10%

2. CRITERIA FOR REPLIES TO REVIEWER COMMENTS

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

B. REVIEW AND SELECTION PROCESS

1. PROGRAM POLICY FACTORS

In addition to the above criteria, ARPA-E may consider the following program policy factors in determining which Full Applications to select for award negotiations:

I. **ARPA-E Portfolio Balance**. Project balances ARPA-E portfolio in one or more of the following areas:
   a. Technological diversity;
   b. Organizational diversity;
   c. Geographic diversity;
   d. Technical or commercialization risk; or
   e. Stage of technology development.

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

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

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

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

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

2. ARPA-E REVIEWERS

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

ARPA-E requires all reviewers to complete a Conflict-of-Interest Certification and Nondisclosure Agreement through which they disclose their knowledge of any actual or apparent conflicts and agree to safeguard confidential information contained in 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

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

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

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

2. FULL APPLICATION NOTIFICATIONS

ARPA-E promptly notifies Applicants of its determination. ARPA-E sends a notification letter by email to the technical and administrative points of contact designated by the Applicant in ARPA-E eXCHANGE. The notification letter may inform the Applicant that its Full Application was selected for award negotiations, or not selected. Alternatively, ARPA-E may notify one or more Applicants that a final selection determination on particular Full Applications will be made at a later date, subject to the availability of funds or other factors.

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

a. SUCCESSFUL APPLICANTS

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

Please refer to Section IV.G.2 of the FOA for guidance on pre-award costs. Please also refer to the "SBIR/STTR Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/?q=arpa-e-site-page/pre-award-guidance-sbir-sttr) for guidance on the award negotiation process.

b. POSTPONED SELECTION DETERMINATIONS

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

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

c. UNSUCCESSFUL APPLICANTS

By not selecting a Full Application, ARPA-E intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. ARPA-E hopes that unsuccessful Applicants will submit innovative ideas and concepts for future FOAs.

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

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

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

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

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

By law, Prime Recipients are also required to register with the Federal Funding Accountability and Transparency Act Subaward Reporting System (FSRS) at https://www.fsrs.gov/.[84] Prime Recipients are required to report to FSRS the names and total compensation of each of the

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

Prime Recipient's five most highly compensated executives and the names and total compensation of each Subrecipient's five most highly compensated executives. Please refer to https://www.fsrs.gov/ for guidance on reporting requirements.

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

Finally, Prime Recipients are required to register with FedConnect in order to receive notification that their funding agreement has been executed by the Contracting Officer and to obtain a copy of the executed funding agreement. Please refer to https://www.fedconnect.net/FedConnect/ for registration instructions.

2. NATIONAL POLICY ASSURANCES

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

3. PROOF OF COST SHARE COMMITMENT AND ALLOWABILITY

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

The Prime Recipient is also required to provide cost share commitment letters from Subrecipients or third parties that are providing cost share, whether cash or in-kind. Each Subrecipient or third party that is contributing cost share must provide a letter on appropriate letterhead that is signed by an authorized corporate representative. Please refer to the "SBIR/STTR Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/?q=arpa-e-site-page/pre-award-guidance-sbir-sttr) for guidance on the contents of cost share commitment letters.

4. COST SHARE PAYMENTS[85]

All proposed cost share contributions for Phase II and Phase IIS of Combined Phase I/II awards and Combined Phase I/II/IIS awards must be reviewed in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

ARPA-E requires Prime Recipients to contribute the cost share amount incrementally during the performance of work in Phase II and/or Phase IIS (as applicable).[86] Specifically, every Prime Recipient is required to contribute, at a minimum, the cost share percentage of total expenditures incurred during every billing period in Phase II and/or Phase IIS (as applicable). For example, a Prime Recipient is required to contribute at least 31% of the total expenditures incurred during every billing period in Phase II if the funding agreement states that the cost share percentage in Phase II is 31%.

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

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

Please refer to the "SBIR/STTR Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/?q=arpa-e-site-page/pre-award-guidance-sbir-sttr) for additional guidance on cost share payment requirements.

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

5. ENVIRONMENTAL IMPACT QUESTIONNAIRE

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

[84] Please refer to Section III.D of the FOA for guidance on cost share requirements.
[85] Prime Recipients may elect to pay the entire cost share amount at the start of the project.

To facilitate and expedite ARPA-E's environmental review, Prime Recipients are required to complete an Environmental Impact Questionnaire during award negotiations. This form is available on ARPA-E's website at http://arpa-e.energy.gov/?q=arpa-e-site-page/pre-award-guidance-sbir-sttr. The Environmental Impact Questionnaire is due within 21 calendar days of the selection announcement.

6. TECHNOLOGY-TO-MARKET PLAN

During award negotiations, Prime Recipients are required to negotiate and submit an initial Technology-to-Market Plan for Phase II and Phase IIS with the ARPA-E Program Director, and obtain the ARPA-E Program Director's approval prior to the execution of the award. During the project period, Prime Recipients are required to provide regular updates on the initial Technology-to-Market plan and report on implementation of Technology-to-Market activities. Prime Recipients may be required to perform other actions to further the commercialization of their respective technologies. Prime Recipients are not required to negotiate a Technology-to-Market Plan for Phase I only awards.

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

7. INTELLECTUAL PROPERTY AND COMMERCIALIZATION RIGHTS AGREEMENT

ARPA-E requires every Project Team to negotiate and establish an Intellectual Property and Commercialization Rights Agreement that governs the management and disposition of intellectual property arising from the project, and allocates rights to carry out any follow-on research, development, or commercialization activities. The Prime Recipient must submit a completed and signed Intellectual Property and Commercialization Rights Agreement to ARPA-E within six weeks of the effective date of the ARPA-E funding agreement. All Intellectual Property and Commercialization Rights Agreements are subject to the terms and conditions of the ARPA-E funding agreement and its intellectual property provisions, and applicable Federal laws, regulations, and policies, all of which take precedence over the terms of Intellectual Property and Commercialization Rights Agreements.

ARPA-E has developed a template for Intellectual Property and Commercialization Rights Agreements (http://arpa-e.energy.gov/?q=arpa-e-site-page/award-guidance-sbir-sttr) so as to facilitate and expedite negotiations between Project Team members. ARPA-E does not mandate the use of this template. ARPA-E and DOE do not make any warranty (express or implied) or assume any liability or responsibility for the accuracy, completeness, or usefulness of the template. ARPA-E and DOE strongly encourage Project Teams to consult independent legal counsel before using the template.

8. U.S. MANUFACTURING REQUIREMENT

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

a. SMALL BUSINESSES

Small businesses (including Small Business Concerns) that are Prime Recipients or Subrecipients under ARPA-E funding agreements are required to substantially manufacture the following products in the United States for any use or sale in the United States: (1) products embodying subject inventions, and (2) products produced through the use of subject invention(s).[87] This requirement does not apply to products that are manufactured for use or sale outside the U.S.

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

b. LARGE BUSINESSES AND FOREIGN ENTITIES

Large businesses and foreign entities that are Subrecipients under ARPA-E funding agreements are required to substantially manufacture the following products in the United States: (1) products embodying subject inventions, and (2) products produced through the use of subject invention(s).[88] This requirement applies to products that are manufactured for use or sale in the United States and outside the United States.

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

[86] Small businesses are generally defined as domestically incorporated entities that meet the criteria established by the U.S. Small Business Administration's "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (http://www.sba.gov/content/small-business-size-standards). Small businesses include Small Business Concerns, as defined in Note 5.

[88] Large businesses are generally defined as domestically incorporated entities that do not meet the criteria established by the U.S. Small Business Administration's "Table of Small Business Size Standards Matched to North American Industry Classification System Codes" (http://www.sba.gov/content/small-business-size-standards).

acquiring a controlling interest in the large business or foreign entity to apply the same U.S. Manufacturing requirements to their licensees.

c. EDUCATIONAL INSTITUTIONS AND NONPROFITS

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

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

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

d. FFRDCs and State and Local Government Entities

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

C. REPORTING

Recipients are required to submit periodic, detailed reports on technical, financial, and other aspects of the project, as described in Attachment 4 to ARPA-E's Model Cooperative Agreement for SBIR/STTR Awards (http://arpa-e.energy.gov/?q=arpa-e-site-page/award-guidance-sbir-sttr).

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

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

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

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

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

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

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

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

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

B. DEBRIEFINGS

ARPA-E does not offer or provide debriefings. However, 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/), FedConnect (https://www.fedconnect.net/FedConnect/), and the Government-wide SBIR/STTR website (http://www.sbir.gov/solicitations). Any modifications to the FOA are also posted to these websites. You can receive an e-mail when a modification is posted by registering with FedConnect as an interested party for this FOA. It is recommended that you register as soon as possible after release of the FOA to ensure that you receive timely notice of any modifications or other announcements. More information is available at https://www.fedconnect.net.

B. OBLIGATION OF PUBLIC FUNDS

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

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

C. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

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

- The rejection of a 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 Notices of Intent, 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 Notices of Intent, Full Applications, and Replies to Reviewer Comments strictly for evaluation purposes. Applicants should not include confidential, proprietary, or privileged information in their Notices of Intent, Full Applications, or Replies to Reviewer Comments unless such information is necessary to convey an understanding of the proposed project.

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

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

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

G. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

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

1. GOVERNMENT USE LICENSE

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

2. MARCH-IN RIGHTS

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

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

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

H. RIGHTS IN TECHNICAL DATA

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

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.
- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E SBIR/STTR awards may be protected from public disclosure for up to four years from delivery of the last deliverables under the agreement. Such data should be clearly marked as described in Attachment 4 to ARPA-E's Model Cooperative Agreement for SBIR/STTR Awards (http://arpa-e.energy.gov/?q=arpa-e-site-page/award-guidance-sbir-sttr). In

addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

I. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

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

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

J. ANNUAL COMPLIANCE AUDITS FOR FOR-PROFIT ENTITIES

If a for-profit entity (including Small Business Concerns) is a Prime Recipient or Subrecipient, an annual compliance audit performed by an independent auditor may be required. For additional information, please refer to 10 C.F.R. § 600.316 and for-profit audit guidance documents posted under the "Coverage of Independent Audits" heading at http://energy.gov/management/office-management/operational-management/financial-assistance/financial-assistance-forms.

IX. GLOSSARY

Applicant: The Small Business Concern 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 Notice of Intent, Full Application, and Reply to Reviewer Comments.

ARPA-E: Advanced Research Projects Agency-Energy.

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

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

DOE: U.S. Department of Energy.

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

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

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

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

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

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

PI: Principal Investigator.

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

R&D: Research and development.

Research Institution: A FFRDC, nonprofit educational institution, or other nonprofit research organization owned and operated exclusively for scientific purposes. Eligible Research Institutions must maintain a place of business in the United States, operate primarily in the United States, or make a significant contribution to the U.S. economy through the payment of taxes or use of American products, materials, or labor.

SBA: U.S. Small Business Administration.

SBIR: Small Business Innovation Research Program.

Small Business Concern: A for-profit entity that: (1) maintains a place of business located in the United States; (2) operates primarily within the United States or makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor; (3) is an individual proprietorship, partnership, corporation, limited liability company, joint venture, association, trust, or cooperative; and (4) meets the size eligibility requirements set forth in 13 C.F.R. § 121.702. Where the entity is formed as a joint venture, there can be no more than 49% participation by foreign business entities in the joint venture.

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

STTR: Small Business Technology Transfer Program.

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.