FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

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

FULL-SPECTRUM OPTIMIZED CONVERSION AND UTILIZATION OF SUNLIGHT (FOCUS)

Announcement Type: ~~Initial Announcement~~ Modification 001
Funding Opportunity No. DE-FOA-0000949
CFDA Number 81.135

FOA Issue Date:	July 16, 2013
First Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5 PM ET, August 15, 2013
Submission Deadline for Concept Papers:	5 PM ET, August 22, 2013
Second Deadline for Questions to ARPA-E-CO@hq.doe.gov:	5PM ET, October 28, 2013~~TBD~~
Submission Deadline for Full Applications:	5PM ET, November 4, 2013~~TBD~~
Submission Deadline for Replies to Reviewer Comments:	December 16, 2013~~TBD~~
Expected Date for Selection Notifications:	January 14, 2014~~TBD~~
Total Amount to Be Awarded	Approximately $30 million, subject to the availability of appropriated funds.
Anticipated Awards	ARPA-E may issue one, multiple, or no awards under this FOA. Awards may vary between $250,000 and $10 million.

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

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

MODIFICATIONS

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

Mod. No.	Date	Description of Modifications
01	09/24/2013	• Added "Required Documents Checklist" for Full Applications on p. 1 of the FOA. • Inserted certain deadlines, including the deadlines for the submission of Full Applications and Replies to Reviewer Comments. See Cover Page and Required Documents Checklist. • Inserted anticipated dates for selection announcement and award of funding agreements. See Cover Page and Section V.C of the FOA. • Added subsection numbers in Section I.E of the FOA. • Inserted descriptions of "System Subcategories" that must be specified by Category of Interest 1A Full Applications. See Section I.E.2.1a of the FOA. • Inserted criteria that ARPA-E will use to evaluate the content Full Applications. See Section IV.D of the FOA. • Inserted Example Block Diagrams and Technology Cost Tables as Section 1.H of the FOA. These Category of Interest 1A instructions and examples provide guidance for completing Full Applications, as specified in the Technical Volume description (Section IV.D.1). • Inserted criteria that ARPA-E will use regarding the Content and Form of Replies to Reviewer Comments. See Section IV.E of the FOA. • Inserted criteria that ARPA-E will use regarding funding restrictions. See Section IV.G of the FOA. • Inserted criteria that ARPA-E will use to evaluate Full Applications. See Section V.A.2 of the FOA. • Inserted criteria that ARPA-E will use to evaluate Replies to Reviewer Comments in Section V.A.3 of the FOA. • Inserted program Policy Factors. See Section V.B.1 of the FOA. • Inserted Full Application Notification language. See Section VI.A.3 of the FOA. • Inserted Administrative and National Policy Requirements. See Section VI.B of the FOA. • Inserted Reporting requirements. See Section VI.C of the FOA. • Inserted information concerning annual compliance audits for for-profit Entities. See Section VIII.J of the FOA.

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REQUIRED DOCUMENTS CHECKLIST

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

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

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

SUBMISSION	COMPONENTS	OPTIONAL/ MANDATORY	FOA SECTION	DEADLINE
Concept Paper	• Each Applicant must submit a Concept Paper in Adobe PDF format by the stated deadline. The Concept Paper must include the following: ○ Technology Description (2 pages max.) ○ Addendum (2 pages max.)	Mandatory	IV.C	5 PM ET, August 22, 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: ○ Technical Approach (1 page max.) ○ R&D Tasks (1 page max.) ○ Block Diagram and Technology Costs (4 pages max.) ○ R&D Strategy (20 pages max.) ○ Technology-to-Market Strategy (2 pages max.) ○ Budget Summary (2 pages max.) ○ Qualifications, Experience, and Capabilities (3 pages max. for each Personal Qualifications Summary) ○ Participating Organizations (1 page max.) ○ Prior Collaboration (1 page max.) ○ Management Plan (1 page max.) ○ Multi-Investigator Projects (2 pages max.) ○ Intellectual Property Strategy (no page limit) • The Technical Volume must be accompanied by: ○ SF-424 (no page limit, Adobe PDF format); ○ Budget Justification Workbook/SF424A (no page limit, Microsoft Excel format) ○ 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) ○ Summary for Public Release (1 page max., Adobe PDF format); ○ Summary Slide (1 page limit, Microsoft PowerPoint format) – Applicants must use the Summary Slide	Mandatory	IV.D	5 PM ET, November 4, 2013~~TBD~~

	template available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov); ○ Completed and signed Business Assurances Form (no page limit, Adobe PDF format); and 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: ○ Up to 2 pages of text; and Up to 1 page of images.	Optional	IV.E	~~TBD~~December 16, 2013

I. FUNDING OPPORTUNITY DESCRIPTION

A. AGENCY OVERVIEW

The Advanced Research Projects Agency – Energy (ARPA-E), an organization within the Department of Energy (DOE), is chartered by Congress in the America COMPETES Act of 2007 (P.L. 110-69), as amended by the America COMPETES Reauthorization Act of 2010 (P.L. 111-358), to support the creation of transformational energy technologies and systems through funding and managing Research and Development (R&D) efforts. Originally chartered in 2007 and funded in 2009, the Agency has made awards to 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.

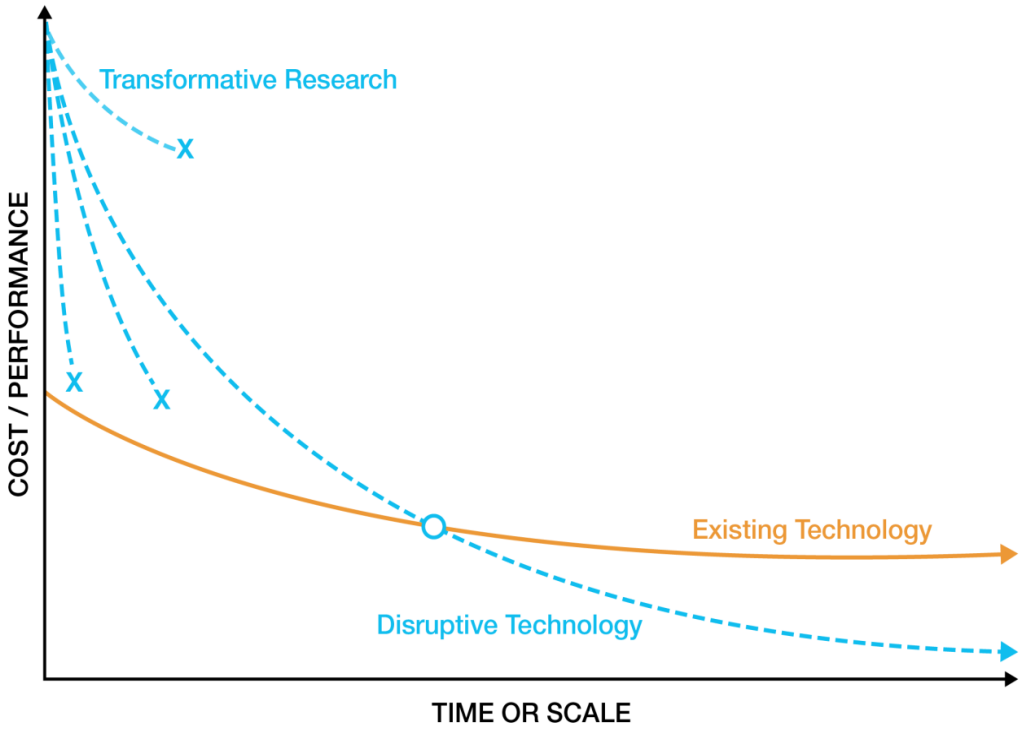

Figure 1: Description of transformational and disruptive technologies in terms of cost per unit performance versus time or scale. ARPA-E seeks to support research that establishes new learning curves that lead to disruptive technologies.

ARPA-E exists to support transformational, rather than incremental research. Technologies develop along learning curves (Figure 1, above). 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 meaningful improvements accrue only slowly. While this incremental improvement of technology is important to the ultimate success of a technology in the marketplace, ARPA-E exists to fund transformational research – i.e., research that creates fundamentally new learning curves rather than moving existing technologies down their learning curves.

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

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

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

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

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

B. PROGRAM OVERVIEW

1. SUMMARY

Through the FOCUS Program, ARPA-E will fund the development of disruptive new technologies to optimally exploit the full solar spectrum and reduce the cost of solar energy when the sun is not shining. Figure 2 schematically illustrates the two technologies addressed by the FOCUS FOA. One category of awards is for new hybrid solar converter technologies to provide both heat, which can be stored at low-cost for later use, and electricity. A second category of awards is for new hybrid storage technologies that can leverage the simultaneous availability of both solar electricity and heat to dispatch solar electricity whenever needed. The devices and technologies that emerge from the FOCUS Program have the potential to go beyond photovoltaic, concentrating solar power and electricity storage paradigms, to dramatically increase the penetration of solar energy into the U.S. energy mix.

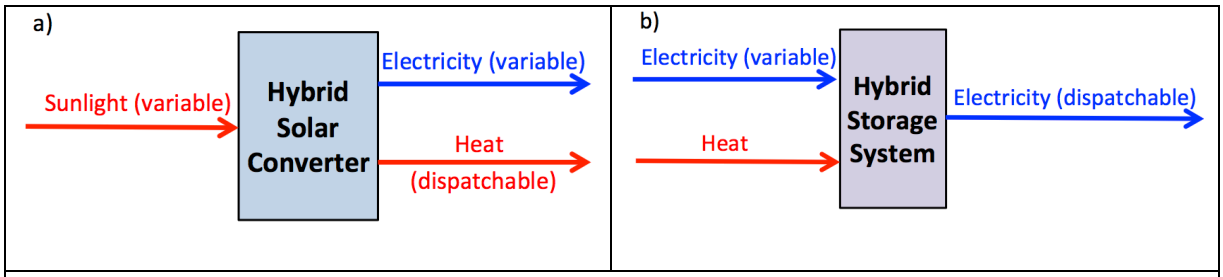

Figure 2. Schematics of technology areas addressed by the FOCUS FOA. a) Hybrid solar converter (award Categories 1A and 1B). b) Hybrid storage system (award Category 2). The term "dispatchable" indicates availability as needed.

2. MOTIVATION

High utilization of solar energy is an important component of future energy scenarios with reduced carbon-dioxide emissions.[2] Solar energy systems can also provide secure energy with predictable future costs, largely unaffected by geopolitics and global energy markets, because sunshine is widely available and free. Despite the impressive technology and deployment advances made by solar photovoltaics (PV), today's high-cost electricity storage options will likely limit PV penetration to less than about 5% of U.S. primary energy before significant PV curtailments will be needed at times of high solar availability.[3, 4] Meanwhile, concentrating solar power (CSP), solar heating and solar hot water applications together contribute less than 0.1% of U.S. primary energy, and their deployment is growing only slowly. *The primary goal of this FOA is to provide disruptive new solar conversion and storage technology options to enable much higher penetration of solar energy generation into the U.S. energy mix.*

[2] O. Edenhofer, *et al.* (eds), Intergovernmental Panel on Climate Change, "Special Report on Renewable Energy Sources and Climate Change Mitigation." (2011) Prepared by Working Group III of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, United Kingdom, 1075 pp.
[3] PV limited to about 10% of electricity without curtailments. IPCC, "Special Report on Renewable Energy Sources and Climate Change Mitigation," (2011) Ch. 8.
[4] Electricity provides about 40% of U.S. primary energy, U.S. Energy Information Administration, Monthly Energy Review (April 2012), Tables 1.3,2.1-2.5.

Electricity generation from sunlight by photovoltaics, through direct conversion using a semiconductor absorber, has grown into a $100 billion per year global industry. This growth is fueled by the availability of increasingly efficient PV modules at rapidly falling prices. In sunny locations with moderate or high electricity costs, PV now provides electricity at prices at or below parity with grid electricity. This "grid parity" is becoming more geographically widespread, accelerating the deployment of PV in the U.S. and globally. Photovoltaics now generate about 0.1% of U.S. electricity, and PV generation is projected to reach 3% penetration in California by 2015.[5] The DOE's SunShot Program supports research and development (R&D) for continued cost reductions and improvements in PV sunlight-to-electricity conversion efficiencies. Despite this momentum, storage of PV electricity remains expensive. The high cost of grid electricity storage makes it best suited for high-value, short-term, frequency regulation; the lower value market for peak-shifted photovoltaic electricity is largely unprofitable, except where geography provides suitable reservoirs for lower-cost pumped-storage hydroelectricity. [6]

Penetration of PV will ultimately be limited unless breakthrough technologies enable hours of electricity generated by PV to be cost-effectively stored. Models of the solar-resource-rich California electricity grid show that PV curtailments will begin at penetrations as low as 12%, while about one-third of PV electricity would be curtailed at penetrations of ~28%.[7] The marginal economic value of installing PV is predicted to fall by half when PV meets more than 20% of the California utility load.[8] The current state of the German electrical grid provides a glimpse into the likely future of grid-parity PV in the United States. In Germany, about 5% of annual electrical energy production is now from solar resources, and solar energy frequently contributes more than 20% of the required grid power on a summer day. [9] This level of solar penetration is enabled only through a combination of demand-side management, trading of surplus power at low cost to neighboring jurisdictions, and dispatch of expensive natural gas peaking or load-following plants. Higher penetration of solar energy would require either slowdowns of generation from baseload plants, a function that they are not designed to perform efficiently, or dumping of surplus solar electricity. A recent analysis finds that a new German program offering up to 660 EUR/kW subsidy for storage tied to PV will not lower battery payback periods enough to induce new investment.[10] Germany's solar incentives now require PV systems to have a curtailment capability, to allow shut-off during periods of grid instability. [11]

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[5] U.S. Energy Information Administration, Annual Energy Outlook (2013)

[6] ARPA-E GRIDS Funding Opportunity Annoucement, https://arpa-e-foa.energy.gov/FileContent.aspx?FileID=98c6222e-471c-4216-a377-024dbdb45549

[7] Denholm, P.; Mehos, M. "Quantifying the Value of CSP with Thermal Energy Storage" Phoenix: SunShot CSP Program Review. (2013) Slide 27

[8] Mills, A.; Wiser, R. "Changes in the Economic Value of Variable Generation at High Penetration Levels: A Pilot Case Study of California."LBNL-5445E (2012).

[9] Burger, B. "Electricity production from solar and wind in Germany in 2012". Freiburg: Fraunhofer Institute for Solar Energy Systems ISE. (2013)

[10] Bloomberg New Energy Finance. "Will Germany's energy storage subsidy spur investment?". London. (2013) p. 1.

[11] Fulton, M. and Capalino, R., "The German Feed-in Tariff: Recent Policy Changes." New York: Deutsche Bank (2012) p. 21

Concentrating solar power systems have long been seen as a potentially attractive alternative to PV from the standpoint of grid integration. CSP generates solar electricity by focusing the direct component of sunlight and collecting the heat to power an electricity-generating turbine. Today, the levelized cost of electricity (LCOE) from CSP is roughly twice that of PV electricity. However, CSP systems have a low incremental cost of heat storage that enables dispatch of electricity when it is most needed. The heat collected is typically stored as sensible heat in molten salts, where the stored thermal energy can be extracted later with almost no loss. Today's cost of this thermal energy storage (TES) is approximately $\$30/kWh_{th}$,[12] equivalent to ~$\$75/kWh_e$[13] and already lower than the aggressive $\$100/kWh_e$ research goals for short-term electrical storage.6

As PV penetration into electricity generation grows, the periods of greatest demand (and highest value) for electricity on the grid will increasingly move outside of PV operating hours.[14] As a result, some U.S. jurisdictions have already bypassed less expensive PV projects in favor of CSP equipped with thermal energy storage, such as Arizona Public Service Company's procurement of 280 MW of CSP capacity.[14] Similarly, in early 2013 the California Public Utilities Commission authorized a utility power purchase agreement from a CSP plant with TES. Although the kWh_e cost was higher than competing PV systems, the Commission deemed the project more valuable because of its operational flexibility.[15] Despite the advantages of low-cost thermal energy storage, however, only about 2 GW of CSP is installed worldwide, compared to about 100 GW of PV.

Today's PV and CSP solutions alone cannot provide the combination of low LCOE and dispatchable output that will be required to enable large-scale solar energy utilization outside daytime hours. Figure 3 schematically illustrates today's low cost of PV electricity, the lack of PV dispatchability, the higher cost of dispatchable CSP electricity, and the high cost of adding electrical storage to increase the dispatchability of PV electricity. The FOCUS Program aims to develop solar energy conversion and storage innovations to economically address energy needs at times when PV electricity is unavailable ("FOCUS" in Figure 3). To succeed, multidisciplinary efforts must develop innovative technologies based on advanced ideas from CSP, PV, storage and other technologies. However, there is scant history of joint work between separate PV and CSP communities that are mainly comprised of scientists and engineers with little overlap in their training and fields of interest. *A secondary goal of the FOCUS Program is to promote collaborations among diverse communities of researchers to develop systems that generate inexpensive dispatchable solar energy.*

[12] Kolb, G.; Ho, C.; Mancini, T.; Gary, J. "Power Tower Technology Roadmap and Cost Reduction Plan.' SAND2011-2419. (2011)
[13] ARPA-E Calculation: Assumes an average CSP steam Rankine turbine efficiency of 40%.
[14] Alpert, B. "Integrating CSP w/ TES into a Utility System" Phoenix: SunShot CSP Program Review. (2013)
[15] California Public Utilities Commission, Resolution E-4545. Pacific Gas and Electric Company requests approval of an amended and restated power purchase agreement with Rice Solar Energy, LLC which is a subsidiary of SolarReserve, LLC. San Francisco. (2013) p. 4

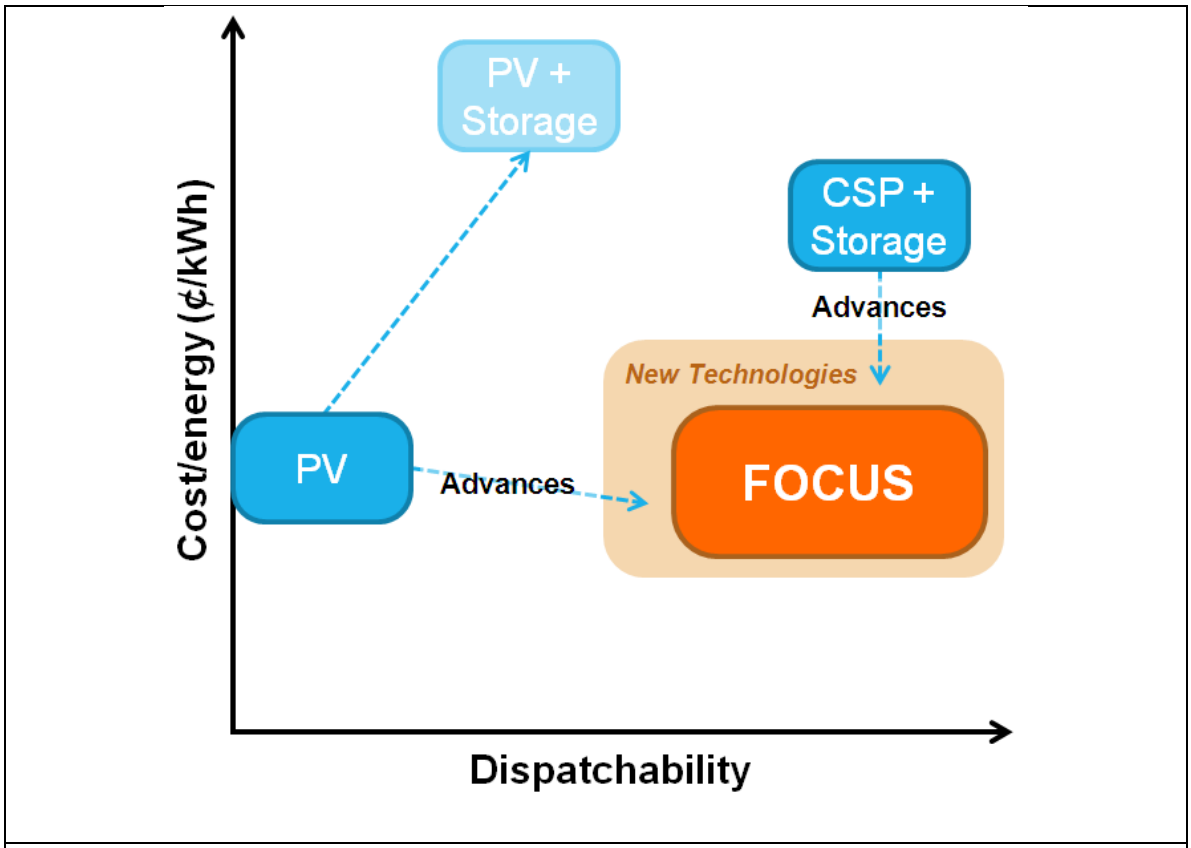

Figure 3. Schematic comparing the cost and dispatchability of PV to CSP with thermal storage. The "PV+Storage" box includes the high cost of electrical storage for PV. The FOCUS Program target zone for electricity generation is indicated.

Finally, ARPA-E has noted a significant barrier that slows the development of current solar power systems with storage capability: new thermal solar plants have extremely high capital costs, often in the billion dollar range, driven by economies of scale in turbines and field construction, as well as the fixed costs of planning and permitting CSP systems. Only about 100 CSP plants are installed worldwide,[16] sharply limiting technology trials and learning cycles. While innovation in utility-scale solar generation remains its central goal, the FOCUS Program also provides opportunities to develop smaller hybrid solar converters and storage systems that can be deployed in lucrative entry markets. Such entry markets enable increased R&D, stimulate mass manufacturing of system components and allow for rapid learning by engineering design iteration — all keys to rapid technology improvement and energy-significant deployment.

The landscapes of future energy generation, distribution, pricing and consumption are complex, but key themes emerge from ARPA-E technology analysis and motivate the FOCUS Program: 1) PV technology is rapidly advancing and has enormous growth potential, but in less than a decade the lack of PV electricity dispatchability will slow solar deployment growth; 2) there is a high risk that conventional electrical storage will be unable to shift significant amounts of PV

[16] http://www.csp-world.com/cspworldmap

electricity to evening and night hours; 3) although CSP can integrate inexpensive thermal energy storage, the cost of CSP solar energy capture is high; and 4) the scale of capital investment associated with CSP is a significant barrier to iteration of designs and rapid innovation.

C. PROGRAM OBJECTIVES

The overarching objective of the FOCUS Program is to create disruptive new solar energy conversion and storage technology options that enable far higher penetration of solar energy into the U.S. energy system than could be expected using only today's PV, CSP and electrical storage options. Technical pathways to this goal include: 1) concentrating hybrid solar energy converters that optimize the utilization of the entire solar spectrum by inexpensively converting sunlight to *both* heat and electricity; and 2) inexpensive hybrid energy storage devices that require *both* electricity and heat as inputs, with electricity as the output. At technology maturity, energy systems incorporating these advanced converters and storage devices will be cost-competitive with other solutions: for example, electricity projects at utility scale will make dispatchable solar electricity competitive with conventional generation. A subsidiary objective of the FOCUS Program is to form a diverse research community (including, e.g., CSP mechanical engineers, PV semiconductor materials and device scientists, optics/photonics experts, chemists, low-cost manufacturing experts and system integrators) who will innovate together. Successful FOCUS projects will reduce energy-related emissions, decrease U.S. dependence on foreign energy sources, and provide U.S. leadership in advanced solar energy technology.

D. TECHNICAL BACKGROUND

1. INTRODUCTION

To stimulate interdisciplinary collaboration among Applicants to the FOCUS FOA, this Section presents technical background to the goals of the FOCUS Program, including calculated efficiencies of some simple technical approaches. The technical examples are meant only to illustrate principles; they are *not* meant to prescribe or limit the technical approaches that might receive an award through the FOCUS Program. ARPA-E is most interested in making awards to Applicants that effectively address a Technical Category of Interest described in Section I.E of the FOA and leads to the development of technology that can meet or exceed the associated Technical Performance Targets specified in Section I.F of the FOA. ARPA-E will make awards only to disruptive solutions that go beyond the state-of-the-art.

2. SOLAR RESOURCE

The amount of solar energy striking the earth in one hour is roughly equal to the amount of primary energy humans use in a year. However, at ~ 1 kW/m^2 power density at the earth's surface, sunlight must be intercepted and then converted to usable energy at high efficiency and extremely low cost per unit collection area. A second challenge lies in the broad spectrum

of incident sunlight, which spans nearly an order of magnitude in wavelength, from about 0.25 to 2.5 µm (0.5 to 5 eV photons). Efficient solar energy systems will require optimal use of the entire solar spectrum. A third challenge is presented by the angular distribution of the sunlight reaching Earth's surface: even the direct component of sunlight has a finite angular width of about 5 degrees,[17] and a significant fraction of sunlight is diffuse in every geographic area, reaching Earth's surface only after scattering in the atmosphere.

3. EXERGY AND HYBRID SOLAR CONVERTERS

Exergy (X) is the maximum usable work that can be extracted from a system at elevated temperature (T) as it comes to equilibrium with a cooler heat reservoir. CSP systems focus and collect heat energy, Q, from a broad spectrum of incident solar photons at a sunlight-to-heat *energy* efficiency of 50 to 80%. Ideally, this solar heat could be converted to electricity by a heat engine at the Carnot efficiency limit of $(1 - T_c/T_h)$ that depends on the ratio between the hot (T_h) and cold (T_c) Kelvin temperatures driving the heat engine. Thus, the *exergy* content, X_{th}, of solar heat collected at T_h is $Q(1\text{-}T_c/T_h)$. To calculate exergy, the FOCUS Program assumes T_c = 310K, as in typical hybrid-cooled heat engines.

One promising path to increasing the efficiency in solar heat-to-electricity systems is to increase the maximum temperature reached by the heat-collecting fluid. The solar spectrum reaching the earth is characteristic of a blackbody with an effective temperature of ~5500°C. Simply collecting solar heat in a thermal fluid at T_h =600°C immediately wastes more than 35% of the incident solar exergy. The DOE SunShot Program and ARPA-E support a range of technologies that could raise T_h in CSP above 600°C, to as high as 1200°C. Increasing T_h would raise the exergy content of the captured solar heat and improve CSP heat engine efficiencies. However, developing systems with T_h above 600°C presents high technical risk. Key technical challenges to overcome include: large heliostat mirror fields that have inherently low optical efficiency and must therefore be extremely low cost; stable thermal fluids; low-cost robust materials for piping, pumping and storing these high T fluids; advanced high T engines (*e.g.*, based on supercritical CO_2); and high efficiency thermal receivers that overcome the problem of radiation losses at high T.

Alternatively, high sunlight-to-exergy efficiency could be obtained with a hybrid solar "topping" converter, while still providing a high fraction of inexpensively stored solar heat. A topping collection device interposed between the sun and the thermal fluid would enable the solar converter to capture more of the solar exergy. For example, photovoltaic cells can collect photoexcited carriers before they relax to thermal equilibrium; the carriers remain at an extremely high "effective temperature" when they are collected as electricity. With effective heat transfer to a thermal fluid, conversion losses in the topping device could be collected as heat for use in a more conventional thermal "bottoming" cycle. Thus, a hybrid solar converter

[17] ASTM E816 - 05, Standard Test Method for Calibration of Pyrheliometers by Comparison to Reference Pyrheliometers (2010)

delivers its energy in two forms: as topping electricity produced when the sun is shining and as heat that can be efficiently stored.

The simplest hybrid solar converter to analyze has a topping device illuminated by concentrated sunlight, which provides its waste heat to an underlying thermal fluid (inset to Figure 4b). The electricity produced directly from sunlight in the topping device is fully available as exergy.[18] Thus, the exergy efficiency η_X of a hybrid solar converter with a topping device providing electric power P_{top} and collecting thermal energy at a rate given by dQ/dt is

$$\eta_X = \frac{\left[P_{top} + \frac{dQ}{dt}\left(1 - {}^{T_c}/_{T_h}\right)\right]}{P_{sun}} , \qquad \text{Eqn. (1)}$$

where P_{sun} is the solar power incident on the converter and the topping device efficiency is $\eta_{top} = P_{top}/P_{sun}$. Assuming that all incident solar energy not converted to electricity is collected as heat, $dQ/dt = (1 - \eta_{top})\, P_{sun}$ and the maximum *exergy* efficiency[19] of this hybrid solar converter is

$$\eta_X = \eta_{top} + \left(1 - \eta_{top}\right)\left(1 - {}^{T_c}/_{T_h}\right) . \qquad \text{Eqn. (2)}$$

This exergy efficiency expresses the fraction of the solar energy collected that can be used to do work without violating the Second Law of Thermodynamics, given η_{top}. However, practical heat engines typically operate at a maximum efficiency of roughly 2/3 the Carnot limit above about 300°C (*e.g.*, ~36% and 42% for engines using T_h = 400°C and 600°C heat, respectively).[20] Therefore, the practical sunlight-to-electricity *energy* efficiency of a hybrid solar converter is

$$\eta_E = \eta_{top} + \frac{2}{3}\left(1 - \eta_{top}\right)\left(1 - {}^{T_c}/_{T_h}\right) . \qquad \text{Eqn. (3)}$$

[18] There is typically a 2- 4 % loss if the power is converted from DC output to grid AC electricity

[19] *Exergy* efficiency is ARPA-E's preferred figure of merit for hybrid solar converters. A practical heat engine could convert only ~2/3 of the exergy in heat to electricity, so Eqn (2) effectively increases the value of the electricity from heat by a factor of ~3/2. While it is impossible to foresee the future time-of-day pricing structure of electricity, a premium factor of at least ~1.5 for dispatchability is likely once local PV penetration is substantial and the peaks of net demand for additional solar electricity (subtracting PV electricity from actual demand) shift to the evening and morning hours.

[20] Sunshot Vision Study (2012), p.115, http://www1.eere.energy.gov/solar/sunshot/vision_study.html

4. EXAMPLE: PV TOPPING DEVICES AND SYSTEM EFFICIENCY

High temperature photovoltaic, thermoelectric, and photothermionic[21,22] devices are some candidates for use as the high T topping devices in concentrating hybrid solar converters. In this sub-section, the potential of single-junction PV as a topping device is analyzed, because PV cells are the most industrially-advanced of these candidate devices. Today, concentrating photovoltaic systems focus direct sunlight onto efficient solar cells to generate electricity. The CPV solar cells are normally operated well below 80°C to maintain high efficiency. To withstand high operating temperatures, re-imagined topping PV cells would need to incorporate robust dopant profiles and contacts, employ features to minimize dark current losses and avoid low-bandgap absorbers.

PV cells could be remarkably efficient at elevated *T* if the bandgap is appropriately chosen and the cell is under optical concentration. Recently, device physics models were employed to estimate the dependence of single-junction PV cell recombination-limited efficiency over their operating *T* (from 100 to 800°C) and their operating bandgap, at optical concentrations between 100X and 2000X.[23, 24] The calculations are consistent with measurements taken across a narrower *T* range under 1-sun AM0 illumination.[25] Figure 4 shows quadratic curve fits to 100X concentration efficiencies in the Shockley-Queisser (S-Q) limit[26] and for a "moderate"-recombination cell that has roughly 2%-absolute lower 1-sun efficiency than today's world record single-junction GaAs solar cell.[27] Both the S-Q and moderate-recombination cells are dominated by radiative recombination. Note that the PV curves in Figure 4 are not representative of a single solar cell: they show the optimum modeled efficiency at each *T* with operating bandgap as a free parameter. For example, the moderate-recombination cell at 100°C has an operating bandgap of about 1.38 eV and the 400°C cell on the same curve has an operating bandgap of about 1.63 eV.[28]

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[21] Schwede, J., *et al.* "Photon-enhanced thermionic emission for solar concentrator systems" *Nature Materials* (2010) ***9***, p. 762.

[22] Tianyin, S.; Koeck, F.; Zhu, C.; Nemanich, R. "Combined visible light photo-emission and low temperature thermionic emission from nitrogen doped diamond films." *Applied Physics Letters* (2011), ***99*****,** p. 202101.

[23] Gray, J., ARPA-E Workshop: "Solar Beyond Grid Parity: Spectrum-Efficient Solar Energy for Dispatchable Electricity or Fuels," (2013), http://www.arpa-e.energy.gov/sites/default/files/documents/files/SolarBeyondGridParity_Gray.pdf

[24] Wilcox, J; Gray, J. , unpublished (2013)

[25] Landis, G. A., et al. "High Temperature Solar Cell Development," NASA John Glenn Research Center, Technical Report (2005), 2005-213431, p. 241.

[26] Shockley, W.; Queisser, H. "Detailed Balance Limit of Efficiency of p-n Junction Solar Cells." *Journal of Applied Physics* (1961) ***32***, p. 510.

[27] Green, M. A., Emery, K., Hishikawa, Y., Warta, W. and Dunlop, E. D. "Solar cell efficiency tables (version 39)." *Progress in Photovoltaics: Research and Applications* (2012), ***20***, p. 12.

[28] This *T* range and variation in bandgap could be achieved in the III-V system or with other semiconductors. If epitaxial materials were used, lift-off cells would likley be needed. As with all concentrator PV cells, the allowed cell cost would increase with concentration ratio.

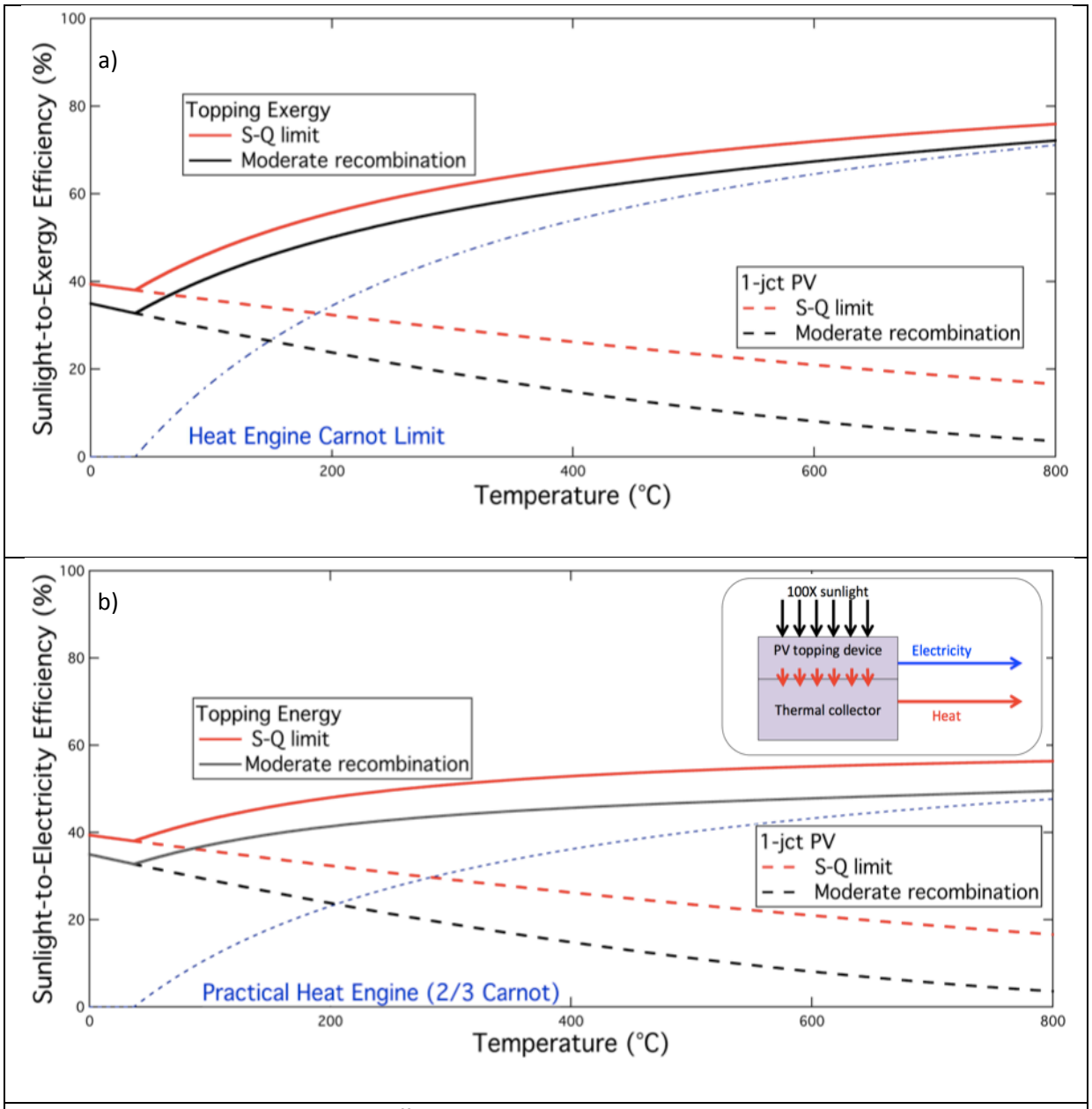

Figure 4. Calculated hybrid solar converter efficiencies versus *T*, using a PV topping device under 100X concentration and assuming 100% optical efficiency. Single-junction PV cells at the Shockley-Queisser limit (red) and with moderate recombination assumptions (black). a) Exergy efficiency at the Carnot limit. b) Electrical energy production efficiency with a practical heat engine at T_h. The inset shows the simple hybrid solar converter modeled, with PV waste heat collected in a thermal fluid.

Figure 4 also shows the results of efficiency calculations using Eqns. (2) and (3) for the simple PV-topped hybrid solar converter system shown in the inset to Figure 4b, under 100X concentration. Perfect optical efficiency is assumed, including ideal PV anti-reflection. The only solar heat flowing into the thermal-fluid loop is waste heat from this PV, which must operate at the highest temperature in the system. Figure 4a shows the sunlight-to-*exergy* efficiency calculated from Eqn. (2) as a function of *T* for bandgap-optimized PV cells. The exergy efficiency varies from about 50% at 150°C to above 70% at 600°C with the S-Q limited PV cell, and is

roughly 5%-absolute lower with the moderate-recombination PV topping cell. Figure 4b shows the Eqn. (3) sunlight-to-electrical *energy* efficiency for the same PV-based hybrid solar converter, now assuming practical heat engines. The energy efficiency limit calculated from Eqn. (2), for moderate-recombination PV, varies from about 40% at 150°C to nearly 50% at 600°C. It is worth noting that the converter reaches the same 46% *energy* efficiency at 400°C as could be reached by a purely thermal CSP system at 700°C.

Hybrid solar converters reach high efficiency by utilizing the solar spectrum more fully than either CSP or PV systems alone.[29] PV cells are extremely efficient in converting photons with energies just above their bandgap into electricity. For example, single-junction GaAs cells illuminated with laser monochromatic light have exceeded 50% efficiency[30] and could be more than 60% efficient.[31,32] However, there is no absorption of photons with energy below the semiconductor bandgap, and thermalization losses to the band edge reduce the efficiency in the blue and ultraviolet.[33] Although increasing the operating *T* lowers the topping PV efficiency, the broad spectrum thermal collection compensates. By converting captured solar heat to electricity, 20-40% of PV losses at every wavelength are recovered.

It is possible to envision many improvements that would raise the converter exergy output above that of the simple hybrid solar converter analyzed in Figure 4. Increasing the concentration ratio to 1000X would increase the 1-junction PV cell efficiency by about 2.5%-absolute,[24] and significant increases in topping efficiency could also be achieved by using multijunction cells. With different converter design, PV cells could be placed in the highest *T* zones but also in illuminated zones where the thermal collection fluid is at a lower *T* and the PV efficiency would be higher. Spectral splitting approaches[34,35] can divert wavelengths converted poorly by PV to a secondary thermal receiver operating at a higher *T* than the PV. In this case, the thermal fluid could reach temperatures higher than the topping PV. Spectral splitting could

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[29] Branz, H.M., ARPA-E Workshop: "Solar Beyond Grid Parity: Spectrum-Efficient Solar Energy for Dispatchable Electricity or Fuels," (2013), http://www.arpa-e.energy.gov/sites/default/files/documents/files/SolarBeyondGridParity_Branz.pdf

[30] Olsen, L.; Huber, D.; Dunhum, G.; Addis, F.; Anheier, N. "High efficiency monochromatic GaAs solar cells." In: *Proceedings of 22nd IEEE Photovoltaic Specialist Conference*. (1991) p. 419.

[31] Green, M. "Limiting photovoltaic monochromatic light conversion efficiency." *Progress in Photovoltaics: Research and Applications* (2001), ***9***, p. 257.

[32] Henley, M.; Fikes, J.; Howell, J.; Mankins, J. "Space solar power technology demonstration for lunar polar applications: laser-photovoltaic wireless power transmission" (2002) Presentation to the World Space Congress, Houston, TX, http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20020091885_2002153397.pdf

[33] Conversion of a wider spectral range of photons in multijunction cells has enabled 44% efficient triple junction cells under concentration. However, voltage loss mechanisms are nearly bandgap-independent [King, R.R., et al, "Bandgap engineering in high-efficiency multijunction concentrator cells." *Intl. Conf. on Solar Concentrators for the Generation of Electricity or Hydrogen*. (2005), Scottsdale, AZ] and limit the ability of lowgap cells to efficiently use solar photons below 1 eV.

[34] Kirkpatrick, D.; Eisenstadt, E.; Haspert, A. "DARPA's Push for Photovoltaics," *Conference Record of the 2006 IEEE 4th World Conference on Photovoltaic Energy Conversion* (2006), ***2***, p. 2556.

[35] Groβ, B.; Peharz, G.; Siefer, G.; Peters, M.; Goldschmidt, J.; Steiner, M.; Guter, W.; Klinger, V.; George, B.; Dimroth, F. "Highly efficient light splitting photovoltaic receiver." *Proceedings of the 24th European Photovoltaic Solar Energy Conference* (2009), p. 130.

be implemented by use of PV that reflects photons it does not process efficiently, as in concentrating PV cavity converters,[36] or by spectrum splitting photonics.

5. HYBRID STORAGE OF HEAT AND ELECTRICITY FOR DISPATCHABLE ELECTRICITY

As described above, hybrid solar converters can be used in systems that produce some dispatchable electricity by storing solar heat. Better storage options for the topping electricity would enable dispatch of *all* the collected solar energy when needed. The simultaneous availability of the solar heat could help store the topping electricity by use of a hybrid storage system, shown schematically in Figure 2b. This system can be viewed as heat-enabled electricity storage and therefore presents different technical opportunities and challenges than the electricity-to-electricity paradigm exemplified by batteries, pumped hydroelectric and flywheel storage. Hybrid storage systems could also be used to enable high penetration of conventional PV into electricity generation. In conjunction with conventional thermal CSP systems or natural gas heat, hybrid storage systems could accept and store grid electricity during sunny hours and dispatch this electricity at any time of day.

High-value hybrid storage systems must be more efficient than a side-by-side combination of today's optimal heat-storage/generation and electrical-storage systems. Quantitatively, for a given ratio of heat to electrical exergy input, the hybrid storage system should return more electrical energy than could be output by a) storing the heat in a 65%-exergy-efficient TES/turbine system[37] and b) independently storing the electricity in an electrical storage system with a round-trip efficiency of 75%. For a given ratio of exergy from electricity to total input exergy, X_{elec}/X_{in}, the desired exergetic efficiency is therefore greater than the weighted average between thermal and electrical storage systems (above the dotted line in Figure 5).

[36] Ortabais, U. U.S. Patent No. 6690049 (2004)

[37] Assumes a steam Rankine turbine operating at about 2/3 of its Carnot limit (vs. 310K) and a TES round-trip exergy efficiency of 97%.

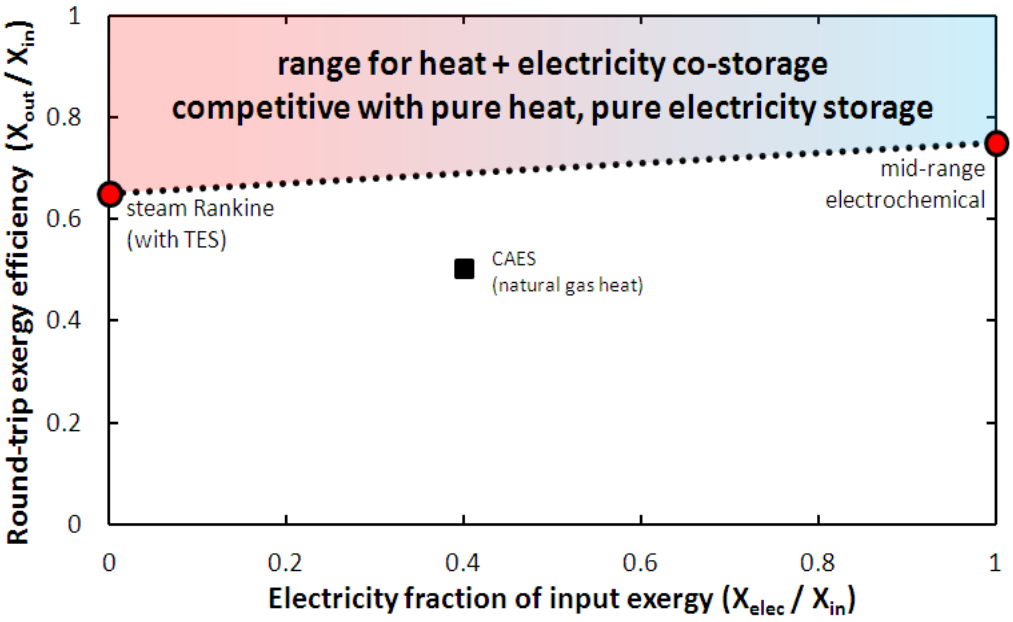

Figure 5. Round-trip exergy efficiency for heat and electricity hybrid storage, competitive with a combination of conventional pure heat and pure electricity storage. The dotted line shows the target of equivalent performance to a weighted average of TES with a steam Rankine and an electrochemical battery. An industrial compressed-air storage plant (CAES)[38] is plotted as an example of a system using electricity and heat inputs to produce dispatchable electricity.

Thermomechanical systems that store electricity by compressing air, but add heat to raise the round-trip efficiency, provide a working example of hybrid storage today.[38] However, the present state-of-the art has not reached the required round-trip exergy efficiency. The black square in Figure 5 shows the exergy efficiency of approximately 50% reached by a commercial system for an exergy input that is about 40% electricity. The system uses the electricity to compress air and, upon discharge, burns natural gas to add heat before expanding the air to drive a turbine.

There are also technical opportunities using electrochemical reactions to produce storable energetic molecules, while also incorporating significant heat inputs. These energetic molecules could be used to generate dispatchable electricity. Many fuel-producing reactions have $\Delta S_{rxn} > 0$, which allows for the input of heat ($T\Delta S_{rxn}$) in addition to electricity (ΔG_{rxn}). For example, a high-temperature electrolysis reaction operating with low overpotential could incorporate external heat into the reaction.[39,40] In this case, the conventional heat engine could be replaced by a fuel cell that might also function, reversibly, as an electrolysis unit. Alternatively, hybrid chemical

[38] EPRI Report TR-101751-V2, "History of First U.S. Compressed-Air Energy Storage (CAES) Plant (110 MW 26h): Volume 2: Construction", S-3 (1994), http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=TR-101751-V2

[39] Hauch, A.; Ebbesen, S.; Jensen, S.; Mogensen, M. "Highly efficient high temperature electrolysis." *Journal of Materials Chemistry* (2008), ***18***, p. 2331

[40] O'Brien, J. "Thermodynamics and Transport Phenomena in High Temperature Steam Electrolysis Cells." *Journal of Heat Transfer* (2012), ***134***, p. 031017.

cycles, which employ a sequence of electrochemical and thermally-driven reactions to perform an overall reaction, have been developed.[41] Research on these hybrid chemical cycles has focused almost exclusively on producing hydrogen transportation fuel, but the approach could be extended to other chemical systems to develop closed, chemically reversible cycles.

E. TECHNICAL CATEGORIES OF INTEREST

1. OVERVIEW

Applications to the FOCUS FOA must demonstrate convincingly that they will provide disruptive technology advancement in one or more of the Technical Categories of Interest described in this Section. Section I.F of the FOA contains the specific technical and cost targets that the proposed technologies must meet. Exceptional systems that combine the functions and targets of both Categories 1A and 2 to meet the overall performance and cost goals of the FOA will also be considered for award. Section I.G of the FOA lists specific technologies that will not be considered for awards.

Technical Category of Interest 1 is the development of critical technologies needed for high sunlight-to-exergy efficiency hybrid solar converters (see Figure 2a) that generate both heat and electricity. ***Category 1A*** applicants must describe the development of advanced hybrid solar converter technologies and prototypes. Applicant must also describe how the hybrid converter will be deployable, at technology maturity, as part of a complete solar system that addresses an energy-significant application space at prices competitive with today's lowest energy costs. ***Category 1B*** applicants must describe the development of novel topping devices that can efficiently convert solar energy directly to electricity at operating temperatures above 400°C. These high-temperature topping devices will enable a second generation of hybrid solar converters. The FOCUS Program does not require integration of ***Category 1B*** topping devices into a complete hybrid solar converter, though Applicants should convincingly describe how the device could be integrated into a converter.

Technical Category of Interest 2 is development of hybrid storage systems for heat and electricity (see Figure 2b) and the critical enabling technologies. These hybrid storage systems must generate electricity at higher round-trip exergy efficiency than is possible today using side-by-side combinations of purely electrical and purely thermal energy storage systems. The cost of a mature hybrid storage system must be low enough to permit topping electricity or PV electricity from the grid to be economically stored for later dispatch.

[41] Perret, R. "Solar Thermochemical Hydrogen Production Research (STCH): Thermochemical Cycle Selection and Investment Priority", SAND2011-3622 (2011)

2. DETAILS ON EACH TECHNICAL CATEGORY OF INTEREST

2.1a. Category of Interest 1A:

Applicants to Category 1A should demonstrate critical technology improvements to enable hybrid solar converters in which the highest temperature of the thermal energy collection is between 150°C and 600°C. This range provides a disruptive change to the state-of-the-art, yet avoids the complications and expense of materials for T_h > 600°C. Utility-scale electricity generation is of particular interest to ARPA-E.

Applicants should propose designs for durable hybrid solar converters that integrate optics, topping devices and thermal receivers, with an optimized balance between heat and topping electricity production, considering both the impacts on system costs and the proposed system application. ARPA-E is interested in proposals that incorporate one or more of the following technological advances to maximize hybrid solar converter exergy efficiency:

- Hybrid solar converters in which a PV topping device is used at an intermediate temperature of a thermal energy collection loop that has a peak T_h incompatible with the efficient use of PV.

- Integrated spectrum-splitting approaches that place a spectrum-sensitive topping device on a secondary reflector that is in contact with the thermal collection loop. The secondary reflector would divert certain wavelength photons (*e.g.*, IR or UV for PV topping) to a higher *T* part of the thermal collection system.

- Spectrally-selective thermal fluids flowing in front of the topping device to selectively absorb photons otherwise poorly utilized in the topping device, including fluids working through nanoparticle absorption.

- Hybrid solar converters that use a topping device other than PV cells, either alone or in conjunction with PV at lower *T*, to raise the system efficiency.

- High-efficiency single-crystal PV cells that are lifted-off reusable substrates for use as topping devices at high *T*. Such PV cells must be designed and tested for 25-year reliability under high *T* cycling or else be extremely inexpensive and incorporated in a converter that allows them to be economically replaced before they degrade.

- Efficient heat extraction from topping devices into the thermal collection medium with minimal loss of exergy.

- Topping devices that are highly efficient within a particular spectral band and are integrated with a hybrid solar converter optical design to selectively direct those wavelengths to the topping devices.

- Optics that economically collect and convert diffuse sunlight to electricity while also concentrating direct sunlight to a hybrid topping converter.

Applicants to Category 1A may benefit from formation of interdisciplinary teams with expertise in more than one of the following areas: non-imaging optics, advanced optics and photonics, mechanical engineering, heat transfer, topping device design and fabrication, low-cost manufacturing, systems integration, reliability and solar system deployment.

Applicants to Category 1A must describe how their proposed hybrid solar converters can be deployed in systems that would scale to provide energy at lower cost than competing technologies. In addition, they must designate a System Subcategory (see below) and provide cost data about the converter and the system in which the converter could be deployed. Section IV.D.1 of the FOA describes the different information that is required to be included in the Technical Volume for each System Subcategory. This system application should be described in sufficient detail for evaluation by reviewers and developed further during the award performance period. ~~Full Applications will be required to include an estimate of the cost per unit exergy delivered by the converter, consistent with guidelines forthcoming from ARPA-E at the Full Application stage of the application process (see Section IV.A of the FOA).~~

System Subcategories.

System applications of the hybrid solar converters in Category 1A must address one of the following System Subcategories:

- System Subcategory UE: Systems that generate *only* utility-scale electricity (UE), as both variable topping electricity and collected heat used to generate electricity. Full Applications are required to include data about the complete system costs, as detailed in the Technical Volume guidelines (Section IV.D.1).

- System Subcategory SE: Small- or intermediate-scale (SE) systems that generate *only* distributed electricity, from hybrid solar converter units that are less than 1000 m^2 in area. Individual units must support promising systems applications. For rapid learning, the applicant must identify a promising market with potential for scale-up. Full Applications are required to include data about the complete system costs, as detailed in the Technical Volume guidelines (Section IV.D.1).

- System Subcategory H: Small-or-intermediate scale systems that directly use the collected heat from hybrid solar converter units which are less than 1000 m^2 in area. For example, a system could use direct solar electricity and heat (without converting solar

heat to electricity) to serve distributed applications such as industrial process heat, district heating, cooling or desalinization. The system described in the application must have an energy-significant market potential in proximity to locations of high direct solar insolation.[42] The system must also efficiently exploit the exergy of the collected solar heat by matching the collection and use temperatures. The system payback time must be estimated and described in the Full Application, using a credible retail value of the electricity and natural gas heat that would be replaced.

2.1b. Category of Interest 1B:

Applicants to Category 1B should propose to develop prototypes of advanced technology concepts for efficient high temperature topping devices that can produce electricity from incident solar energy while achieving high effectiveness in transferring the waste heat to a thermal fluid at $T \geq 400°C$. The devices should operate under solar concentration and eventually be manufacturable at costs compatible with a hybrid solar converter that produces exergy at below $1/W. The solar-to-electricity targets specified in Section I.F are set to ensure these devices could improve the efficiency of a second-generation of hybrid solar converter.

Within Category 1B, ARPA-E is interested in proposals that incorporate one of the following technological advances:

- Innovation to enable efficient PV in this temperature range;
- Devices exploiting photothermionic emission or other high temperature effects to convert sunlight to electricity; and/or
- Novel approaches to high T solar conversion.

2.2 Category of Interest 2:

Category 2 applicants should propose innovative systems that co-store heat and electricity and later output electricity, while demonstrating the performance of critical enabling components for the system. These systems must provide high round-trip exergy-to-electricity efficiency with the cost of storage below the cost available from a combination of today's TES/turbine systems and advanced grid-scale electricity storage. The desired hybrid system should be technologically distinct from pure solar heat storage/generation with a heat engine, and also distinct from pure solar electricity storage (*e.g.*, batteries or flywheels). The most useful systems will be flexible enough to accept a range of heat-to-electricity ratios of the exergy input.

ARPA-E is interested in proposals for storage systems able to accept solar heat input, including systems that may share some elements with today's CSP plants (*e.g.,* inexpensive molten salt

[42] Fox, D.; Sutter, D.; Tester, J. "The thermal spectrum of low-temperature energy use in the United States." *Energy & Environmental Science* (2011) ***4***, 3731-3740 and associated "Supplementary Information"

storage and/or the use of a steam Rankine turbine). In this case, novel technology elements must be added to efficiently store electricity at the same time. ARPA-E is also interested in hybrid storage systems with non-turbine-based but cost-competitive methods of electricity generation. The hybrid storage system cost target is set in Section I.F of the FOA at ~$100/kWh$_e$.[43]

Within Category 2, ARPA-E is interested in proposals that incorporate one or more of the following technological advances:

- Thermomechanical approaches for mechanical storage with advanced heat management.
- Thermomechanical approaches utilizing both cold storage and hot storage, to raise the system Carnot efficiency
- Chemical approaches that make energetic molecules by alternating thermal and electrochemical reactions.
- Chemical approaches that make energetic molecules by high-temperature endothermic electrochemistry.
- Storage systems incorporating solar photochemical inputs to reactions driven mainly by heat and electricity.
- Chemical approaches that make non-gaseous molecules, for ease of storage.

F. TECHNICAL PERFORMANCE TARGETS

Proposed technical plans must show a well-justified, realistic potential for the technology to meet or exceed the quantitative Technical Performance Targets described below. The Performance Targets in each Category are supplemented by explanations below each Table in this Section. Prototypes developed under the work plan should credibly approach all the listed *technical* targets.

[43] ARPA-E electricity cost calculation follows the ARPA-E GRIDS FOA, https://arpa-e-foa.energy.gov/FileContent.aspx?FileID=98c6222e-471c-4216-a377-024dbdb45549, $100/kWh$_e$ storage cost needed to shift $0.06/kWh$_e$ PV electricity to $0.09/kWh$_e$. This assumes a 30-year daily cycling for ~11,000 cycles, round-trip efficiency (RTE) of ~0.75, and storage system costs including both power-proportional (C_p)and energy-proportional (C_E) costs:

Total capital cost target of $100/kWh$_e$ = C_p ($/kW$_e$)/10h + C_E ($/kWh$_e$)
Storage cost per cycle = [C_p ($/kW$_e$)/10h + C_E ($/kWh$_e$)/RTE]/(# of cycles)
Output elec. cost ($/kWh$_e$) = Input elec. cost ($/kWh$_e$)/RTE + Storage cost per cycle ($/kWh$_e$)

1. Category of Interest 1A

Hybrid solar converters

Table 1. Performance Targets for Technical Category 1A

ID	Category	Value (Units)
1A.1	Exergy efficiency of converter with output heat temperature of T_h (°C)	> 30 + [(T_h-200)/40] (%)
1A.2	Fraction, $f_{th}=X_{th}/X_{tot}$, of delivered exergy as heat	0.50 < f_{th} < 0.90
1A.3	Temperature of heat provided by converter, T_h	150 – 600 °C
1A.4	Collection area of prototype converter	0.5 to 25 m^2
1A.5	Cost per unit of delivered exergy from converter	< $1/W
1A.6	Field life of manufactured converter	25 years
1A.7	*Intermediate-scale application unit area*	< 1000 m^2

Supplementary Explanations of Category 1A Metrics

1A.1. For example, if T_h=400°C, the converter exergy efficiency must be at least 35%. The hybrid solar converter provides heat at T_h and electricity with its primary aperture exposed to 1000 W/m^2 of direct AM1.5D light and 150 W/m^2 of diffuse AM1.5G light. Assume P_{sun} =1000 W/m^2 in Eqn. (1), even if the converter produces power from the diffuse component. Assume T_c= 37°C and calculate thermal exergy as X_{th}= $Q(1-T_c/T_h)$. Realistic (not ideal) treatment of thermal and optical losses must be included.

1A.2. The total exergy delivered from the converter is $X_{tot}=X_{elec}+X_{th}$.

1A.3. Temperature of thermal fluid exiting converter during operation.

1A.4. Collection area refers to the primary solar aperture of the reflector or lens. Within this size range, the prototype must be large enough to demonstrate key technical concepts and enable modeling of a full-size unit. Small prototype hybrid converters are acceptable if they reach the required temperature, T_h.

1A.5 Cost of converter per unit exergy produced when the primary aperture is exposed to 1000 W/m^2 of direct AM1.5D light and 150 W/m^2 of diffuse AM1.5G light. Converter cost includes a mechanism that allows collection of a full day's solar energy, with solar

tracking accuracy of < 4 mrad, unless otherwise justified. Full Applications are required to estimate of the cost per unit exergy delivered by the converter, following the example of Table 4 (See Section I.H).

1A.6 Full Applications must provide a realistic estimate of component and hybrid solar converter lifetime (field life until efficiency is reduced by 20% from the rated performance) and describe features promoting longevity. Full Applications should also describe testing plan to ensure long life and accurate solar tracking against daily cycling to T_h, sustained winds of 85 mph, and optical surface cleaning.

1A.7 Size of hybrid converter unit meeting 1A.1-1A.6 targets. *This constraint applies *only* if the proposed system application of the hybrid solar converter application is distributed generation by small- or intermediate-size systems (Subcategories SE and H). No size limits apply to the converter if it is intended *only* for utility-scale generation systems (Subcategory UE).

2. CATEGORY OF INTEREST 1B

High temperature topping devices

Table 2. Performance Targets for Technical Category 1B

ID	Category	Value (Units)
1B.1	Operating temperature of solar topping device	> 400°C
1B.2	Sunlight-to-electricity efficiency of topping device	> 25%
1B.3	Cost per unit area of sunlight intercepted	< $20 x C ($/m^2)
1B.4	Field lifetime of device	25 years

Supplementary Explanations Category 1B Metrics

1B.1. Applicants must specify how the device can be integrated into a hybrid solar converter to effectively transfer its waste heat at above 400°C to a thermal fluid or other medium from which it can be utilized.

1B.2. Solar power conversion efficiency to electrical power when the topping device is exposed to *C* x 1000 W/m^2 of AM1.5D spectrum at the operating *T*. Realistic (not ideal) treatment of optical and thermal losses must be included. Concentration factor *C* must be between 100X and 1000X. Full Applications should specify how this efficiency will be measured.

1B.3. Cost of manufactured topping device per unit area of sunlight intercepted. *C* is the concentration ratio at which 1B.2 efficiency exceeds the target of 25%. For example, if *C*=100, topping device cannot exceed $2000/m^2. ARPA-E understands that not all Applicants will have access to sophisticated cost modeling, but Full Applications must provide a good estimate of eventual mass-production costs based on materials costs and comparable manufacturing processes.

1B.4. Full Applications must make an estimate of device field lifetime to loss of 20% of rated efficiency at the operating *T*, describe features providing longevity and propose a timely testing plan.

3. CATEGORY OF INTEREST 2

Hybrid storage of heat and electricity providing electricity as the output

Table 3. Performance Targets for Technical Category 2

ID	Category	Value (Units)
2.1	Rated output electric power of system prototype	> 20 kW
2.2	Electrical fraction of input exergy, $f_{el} = X_{elec}/X_{in}$	$0.30 < f_{el} < 0.80$
2.3	Round-trip exergy efficiency X_{out}/X_{in} of system	$65 + 10\, f_{el}$ (%)
2.4	Charge and discharge time of storage	10 hours
2.5	Scalability of system for grid-scale application	>10 MW
2.6	Full-scale system capital cost per unit of rated output of stored energy	< 100 $/kWh$_e$
2.7	Temperature of heat input	> 200°C
2.8	Cycle life of full-scale system	> 10,000
2.9	Field lifetime of full-scale system	25 years

Supplementary Explanations of Category 2 Metrics

2.1. Applicant must propose to make a prototype system with *at least* 20 kW power rating, but should prototype and test a larger system if it is needed to provide high confidence in the performance of the eventual full-scale system. If prototype of the required size would require great expense for well-understood components, Applicants may prototype

only the high-risk and novel system components at large scale. Full Applications must specify how demonstration of these elements will ensure full system success through a program of test and modeling.

2.2 Total exergy input to the system is $X_{in}=X_{elec}+X_{th}$ (see Fig. 1b). Assume T_c= 37°C and calculate thermal exergy as $X_{th}= Q(1-T_c/T_h)$.

2.3 Target for the systems depends on the fraction of input exergy that is from electricity, as shown by dashed line in Fig. 4. Total system exergy input is $X_{in}=X_{elec}+X_{th}$. Loss of stored exergy from fully-charged state must also be less than 4% during 24 hours storage without intentional discharge.

2.4 System should have at least 10 hours of storage capacity at the rated power. The maximum time allowed to fully charge system is also 10 hours.

2.5 System must be scalable at full size to *at least* 10 MW rated power.

2.6 Cost projected for a full-scale system with rated power of at least 10 MW, with exactly 10 hours of storage capacity. Capital cost includes a) components with cost proportional to power generated (C_p, in \$/kW_e), including power conditioning to grid electricity, and b) components with cost proportional to stored energy (C_E in \$/kWh_e) including energy storage media. Capital cost calculated as [C_p/10h + C_E]. ARPA-E understands that not all Applicants will have access to sophisticated energy storage systems cost modeling. It is expected that all Applicants will make a strong effort to justify how the technology holds promise to reach this cost target. This system defines a common basis for cost estimation; however, applicants may anticipate commercializing full systems with different or flexible storage capacity, depending upon the application.

2.8 Projected cycle life of full-scale system based on testing of novel components and documented industrial experience for widely-used components. Cycle life is defined as the number of cycles before suffering a >20% reduction in energy or power capability.

2.9 Full Applications must make a realistic estimate of the full-scale system field lifetime before loss of 20% of rated performance and describe features providing longevity.

4. SEEDLING AWARDS FOR PROOF-OF-CONCEPT OF NOVEL PARTIAL SOLUTIONS

ARPA-E recognizes that there may be new high-impact ideas related to these Technical Categories that are exploratory in nature and may not yet be mature enough to meet the scale and degree of validation to approach the Technical Performance Targets, above. For such unproven and yet promising ideas, the FOCUS program may fund smaller Seedling applications to conduct experiments to achieve a proof-of-concept. In Seedlings, the proof-of-concept experiments must be designed in a way that the results obtained clearly indicate paths to

approach full system applicability. The full application must describe how the proposed innovation will enable development of disruptive technologies that can meet the Performance Targets (above) in the relevant Technical Category. See Section II.A, below, for further Seedling Award information.

G. APPLICATIONS SPECIFICALLY NOT OF INTEREST

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

- Solar converters that collect heat from sunlight without an integrated topping device or cycle.
- Solar converters that produce only non-dispatchable electricity from sunlight (for example, purely photovoltaic systems).
- Improvement to thermal fluids or other heat storage materials that are not integrally incorporated into a hybrid solar converter.
- Improvement to heat engines that are not integrally incorporated into a hybrid solar converter or hybrid storage system.
- Hybrid solar converters with maximum thermal fluid or other storage temperatures outside the range from 150 to 600°C.
- Improvements to 1-sun silicon photovoltaic cells or their manufacturing processes
- Improvements to 20 – 80°C solar cells or any solar cells not intended for integral incorporation in a hybrid solar converter system.
- Improvements to existing technologies utilizing heat inputs, including cooling and desalinization, that are not integrally incorporated into a hybrid solar collector or hybrid storage system.
- Thermomechanical storage systems utilizing electricity *only* for parasitic loads such as pumping or monitoring electronics.
- Thermochemical storage systems utilizing electricity *only* for parasitic loads such as pumping or monitoring electronics, without significant electrical input to the reactions.
- Electrical storage systems that do not accept significant heat inputs, for example conventional flow batteries operating near room temperature, or conventional flywheels.

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

H. Instructions and Examples for Category 1A Full Application Block Diagrams and Cost Tables

All Full Applications in Category of Interest 1A are required to provide Block Diagrams and Cost Tables, as specified in the Technical Volume description (Section IV.D.1). In this Section, ARPA-E provides examples of the two Block Diagrams and two Cost Tables that are required for a topping Hybrid Solar Convertor used for producing utility-scale electricity (Subcategory UE). **The example provided here is not meant to define or limit the technologies of interest to ARPA-E**

in any way; it is included only to illustrate and explain the content to be included in the Full Application. The formatting in the Full Application need not follow these examples exactly; formatting should be designed for maximum clarity. **However, the column names for the Cost Tables should be the same as the examples provided here**. The ARPA-E Block Diagram and Cost Table example is similar to the topping systems analyzed in Figure 4b, above. Because this example is provided for illustrative purposes only, it *does not* meet the Category 1a cost target (1A.5) found in Table 1. The example *does* meet the Category 1A exergy targets (1A.1 and 1A.2)

Applicant-provided information may be used to evaluate whether the proposed technology can have electricity and capital costs low enough when mature to create a disruptive impact on solar energy generation systems. Applicants should therefore consider key system trade-offs. For example, increasing the hybrid converter outlet temperature means higher heat engine efficiency and lower $/kW for the power plant, but it may also increase the cost of the working fluid and thermal storage. Applicants should consider that ARPA-E values dispatchable energy at a premium of 1.5X relative to variable electricity provided while the sun shines.[19] Table 1 contains the primary metrics to be met or exceeded by the technology (Section I.F.1).

First Block Diagram: Hybrid Solar Converter

All Category 1A applications (Technology Development or Seedling) must provide a clear Block Diagram showing estimates of component energy efficiencies, quantities of exergy output, and significant energy losses for the proposed hybrid solar converter at technology maturity. The hybrid solar converter extends from the solar aperture through DC electricity and heat output (e.g., in a hot fluid). Figure 6 shows a block diagram for a simple hybrid solar converter design. The example system consists of a parabolic trough with single-axis tracking and a one-junction GaAs wafer solar cell that is well-coupled thermally to the absorber tube.

For each component block of the hybrid converter, the Block Diagram must include the following:

- Power-in and power-out per m^2 of sunlight collection area, beginning from the solar input allocation described in the notes to the Technical Target 1A.1 (Table 1). The electrical and thermal power output from the hybrid solar converter must be indicated, along with the temperature of the heat provided and the exergetic power output. Each block should be labeled by its conversion efficiency when applicable.
- Significant optical losses associated with each component, including internal shading, , spillage of energy reaching the mirror but not the receiver, and reflection and absorption of lenses and other nominally-transparent materials.
- Angular distribution of incident light due the finite solar disk and concentration, including effects on the sharpness of spectral splitting. A Phoenix location should be assumed for average solar elevation.
- Significant thermal losses associated with working fluid and thermal storage, including energy used to maintain hot component temperatures overnight.

- An average loss value across the entire system for any losses that vary from collector to collector in the solar field (e.g., optical losses that depend on heliostat position relative to a solar tower).

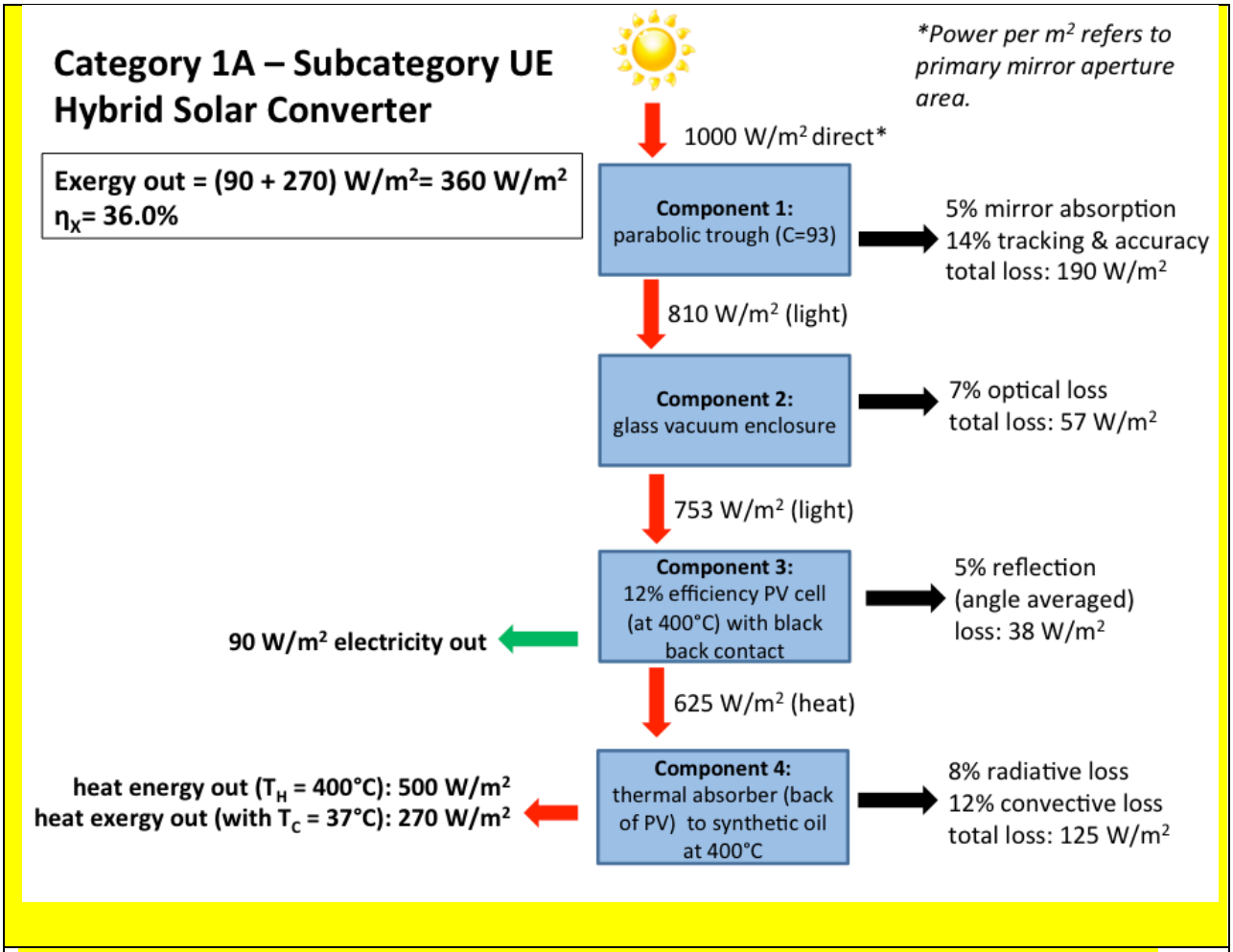

Figure 6. Example hybrid solar converter Block Diagram for a Figure 4b topping converter.

Table Estimating Hybrid Solar Converter Cost

Table 4 shows an example of the Cost Estimate Table corresponding to the hybrid solar converter diagramed in Figure 6. All Category 1A Technology Development applications must include a Cost Estimate Table to provide a direct capital cost (per m^2) estimate for the manufactured hybrid solar converter, with each component itemized by its component number in the Block Diagram. (The full Cost Estimate Table is optional for Seedlings, but they must

provide a justified cost estimate for mass manufacturing of the specific technology they propose to develop).

Costs for significant *subcomponents* must also be itemized in the Table. The cost per unit sunlight collection area of the entire hybrid solar converter must be estimated. The cost per unit exergy from the hybrid solar converter ($\$/W_X$) must be calculated and included in the last line of Table 4. This is obtained by dividing the total cost per unit area (Figure 6 Block Diagram) by the exergy output per unit area.

Applicants should make realistic estimates of the lowest costs that can be achieved, assuming mass manufacturing of complex components. Tables 5 and 6 provide today's costs as starting points. If an applicant's Table 4 entry falls below these costs, a justification (through reference and logical inference) must be included. Specifically,

- Table 5 provides collector component cost estimates for heliostats and troughs, in $\$/m^2$ of aperture area, as compiled by aggressive road-mapping efforts.
- Estimates based on a realistic bill of materials or today's commercial products are permitted. Table 6 provides materials cost assumptions for aluminum, glass and steel.
- For any components under concentration, provide the cost *per unit sunlight collection area*. In Table 4, the actual cost per m^2 of the topping PV cell is divided by the concentration factor of the parabolic trough.
- Include assembly costs of 10% after totaling the item costs.

Table 4. Hybrid Solar Converter Cost Estimate Example

Component	Component Subcategory	Component Type	Cost Calculation (based on area of converter)	Description/Justification
1	**Parabolic trough collector**		**$219/m^2**	Total of subcomponents 1a-1f
	1.a	Mirror Modules	$48/m^2	Aluminum with spectral reflector and protective coating; Estimate from FOA Table 2
	1.b	Sun Tracker	$4/m^2	Single Axis Tracking; FOA Table 2
	1.c	Pedestal Mirror Support Structure and Foundation	$18/m^2	FOA Table 2
	1.d	Controls and Wired Connections	$8/m^2	FOA Table 2
	1.e	Installation and checkout	$62/m^2	FOA Table 2
	1.f	Collector Frames	$79/m^2	FOA Table 2
2	**Glass Vacuum Enclosure**		**$70/m^2**	Includes receiver tubes and fittings; FOA Table 2
3	**GaAs PV on GaAs wafer**		**($20000/m^2)/93= $215/m^2**	Cost quote per m^2 of GaAs wafer. Epitaxial device + 20% extra to accommodate high T design. 93X concentration.
4	**Thermal Absorber**		**$90/m^2**	Total cost of subcomponents 4a-4d. NREL *Line-Focus Solar Plant Cost Reduction Plan (2010)*
	4.a	Piping	$50/m^2	pg 6.
	4.b	Heat Transfer Fluid	$22/m^2	Synthetic Oil; pg 6.
	4.c	Pumps	$6/m^2	pg 6.
	4.d	Other	$12/m^2	pg 6.
Subtotal $/m^2			**$594/m^2**	Sum of above
Assembly Costs			**$59.4/m^2**	10% of total cost must be included
TOTAL COST PER UNIT AREA			**$653.4/m^2**	
TOTAL COST PER UNIT EXERGY ($/W$_x$)			**($653.4/m^2)/(360 W/m^2) ~$1.82/W$_x$**	**NOTE: This example System would not meet the $1/W$_x$ Target**

Table 5. Collector Cost Estimates for Mass Manufacturing

Collector Component Costs	Heliostat ($/m^2)	Trough ($/m^2)
	Source: Power Tower Roadmap and Cost Reduction Plan, Sandia 2011	Source: Line-Focus Solar Power Plant Cost Reduction Plan, NREL 2010
Mirror Modules	25	48
Drives / Trackers	29	4
Pedestal, Mirror Support Structure, Foundation	44	18
Controls and wired connections	4	8
Field Wiring	8	N/A
Installation and Checkout	7	62
Receiver Tubes & Fittings	N/A	70
Collector Frames	N/A	79

Table 6. Commodity Costs

Commodity	Cost ($)	Source
Aluminum	1744/tonne	London Metals Exchange
Flat glass	20/m^2	ARPA-E estimate
Curved glass	35/ m^2	ARPA-E estimate
Steel	135/tonne	London Metals Exchange

Second Block Diagram: System Application

Figure 7 shows a simplified example Block Diagram of a UE system application of the Figure 6 hybrid solar converter. In addition to the hybrid solar converter Block Diagram (above), all Category 1A Technology Development applications must provide a Block Diagram of the intended system application. (This second Block Diagram is optional for Seedlings). For simplicity, ARPA-E requires the applicant to present a Block Diagram of a standard size system. Note that proposed system applications discussed in the Full Application should be sized to provide the best commercial opportunity, and need not have a standard size. The standard system in the Block Diagram must meet the following specifications:

- All UE and SE systems require 10 hours of thermal energy storage.
- For Subcategory UE, the nameplate capacity for the thermal-to-electric system is 250 MW_e.
- For Subcategory SE, the nameplate capacity for the thermal-to-electric system is 250 kW_e.

This Block Diagram of the System Application should clearly show:

- The System Application type (UE, SE or H).
- Daily energy inputs from the hybrid solar collector, based on the power outputs from the Block Diagram of Fig. 6. Assume 6.5 h/d of 1000W/m^2 sunlight, corresponding to Phoenix,[44] or justify any exceptions based on *special features of your technology*.
- Daily energy-in and energy-out for each component of the system. Daily energy losses in percent for each component of the systemParasitic energy consumed (*e.g.,* trackers, pumps and nighttime heating).
- Appropriate fractional division between direct (variable) use and stored (dispatchable) use of the heat (6.5/16.5 and 10/16.5 in Fig. 6).
- Final system output in units of kWh/m^2-day, divided into categories of variable electricity and dispatchable electricity. (Subcategory H may show variable and dispatchable heat, displaced natural gas heat or displaced electricity as outputs).

[44] See http://rredc.nrel.gov/solar/pubs/redbook/PDFs/AZ.PDF

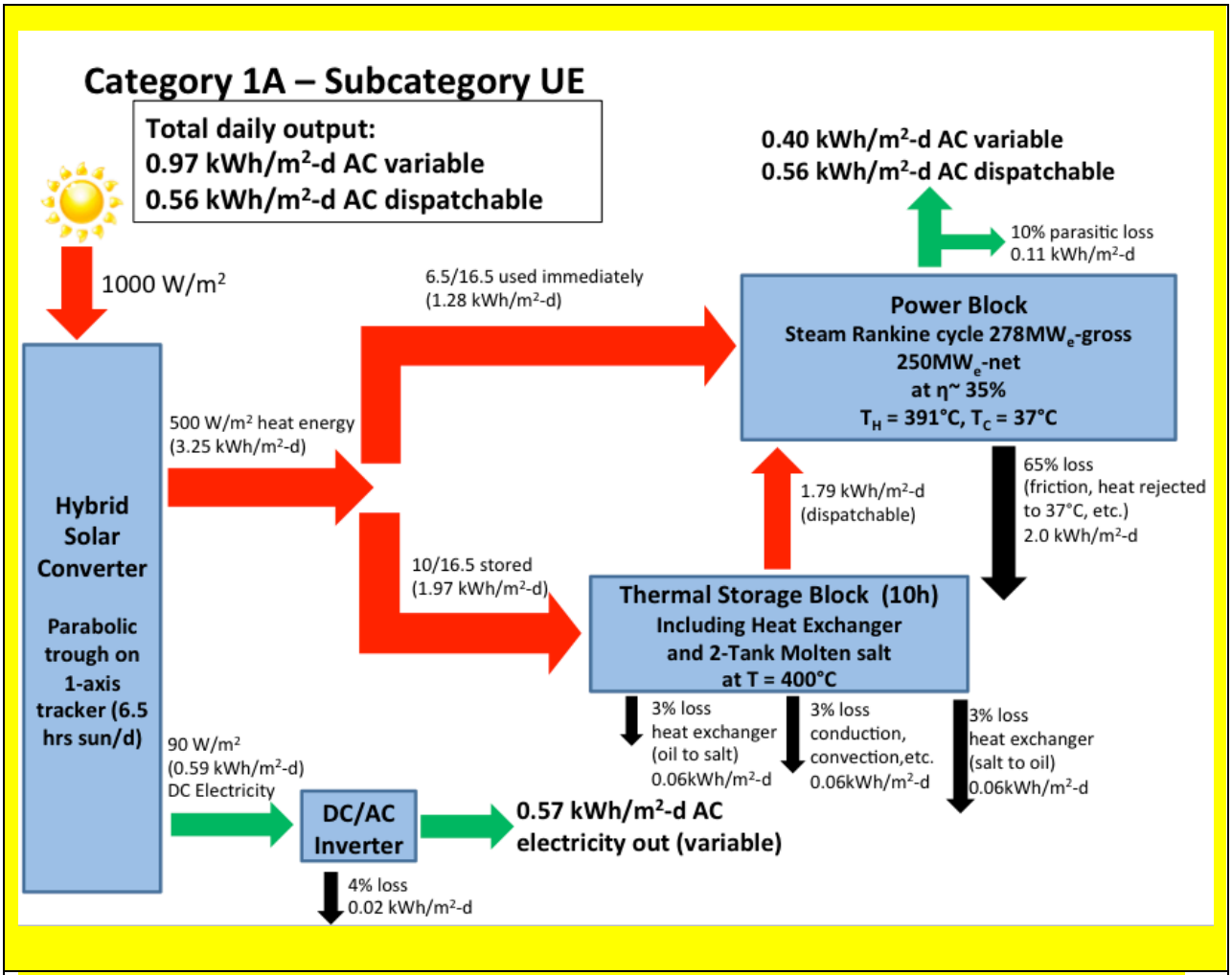

Figure 7: Example Block Diagram for the system application of a hybrid solar converter used to generate electricity at utility scale.

Table of Unit Costs for System Application Components

Table 7 shows an example of the System Component Cost Table corresponding to Figure 7. Applicants for Technology Development Awards in Subcategories UE and SE must provide this Component Cost Table corresponding to their system Block Diagram, but applicants are *not* expected to calculate the total system cost or LCOE. This Cost Table should include all direct capital costs (cost to purchase equipment and labor to install), but should *not* include indirect costs (permitting, engineering, land acquisition, site preparation, O&M, or costs associated with financing). Applicants should make aggressive but realistic cost estimates, assuming inexpensive mass manufacturing.

While standard component costs are well-known, many novel systems require non-standard components. Applicants must specify the costs of both standard and non-standard components

needed in the system. All unit costs must be justified. For example, thermal storage at unusual temperatures may require new thermal fluids whose unit cost must be included. Table 4 shows an example set of system components. The Table 7 component costs can be used directly by applicants if the proposed system uses these standard components in the same way (*e.g.*, at same temperature); any lower costs must be justified. Costs of components used at different temperatures must be justified (through reference and logical inference).

Table 7. Example: Table of Unit Costs for System Application Components

Direct Capital Cost	Unit Cost	Description
Hybrid Solar Converter	$653.4/$m^2$	From Table 1, per m^2 of aperture area
Thermal Storage (10h) Molten Salt 400°C	$80/$kWh_{th}$	Molten Salt 2-tank storage system. Capacity for this system is 7,943 MWh_{th} = 278MW_e x 10h/0.35. NREL Line Focus Solar Plant Cost Reduction Plan, p. 21
Power Block Steam Rankine	$875/$kW_e$-gross	Based on rating of power block of 278 MW_e-gross. Includes Balance of Plant NREL Line Focus Solar Plant Cost Reduction Plan, p. 21
Inverter for DC-to-AC	$0.10/W	Based on SunShot Vision Study 2012, p. 79 and p. 85

Full applications addressing Category 1A and 2 simultaneously in a single inseparable system, must provide a system Block Diagram combining relevant features of Figures 6 and 7 and component cost estimates providing comparable information to Tables 4 and 7. The calculations should estimate the dispatchable electricity fraction for the system.

Full applications proposing Category 1a hybrid converters for Subcategory H must provide a system Block Diagram and estimate the system payback time using a credible retail value of the electricity and natural gas heat that would be replaced. More detail is in Section I.E.2.1a.

II. AWARD INFORMATION

A. AWARD OVERVIEW

ARPA-E expects to make approximately $30 million available for new awards under this FOA, subject to the availability of appropriated funds. ARPA-E anticipates making approximately 8-15 awards under this FOA. ARPA-E may issue one, multiple, or no awards.

Individual awards may vary between $250,000 and $10 million. ARPA-E will provide support at the upper ranges only for applications with significant technology risk, aggressive timetables, and careful management and mitigation of the associated risks.

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

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

ARPA-E may issue awards as one or both of the following funding types: "Proof-of-Concept Seedling Project" and "Technology Development Project."

- **Proof-of-Concept Seedling Project:** Proof-of-Concept Seedlings are projects which both range between $250,000 and $1 million and have a period of performance of no more than a year. If both of these criteria are not met, the project is a Technology Development Project. Seedling projects typically focus on early-stage, proof-of-concept level R&D efforts. Applicants should submit evidence of an idea, described in sufficient technical detail to allow reviewers to meaningfully evaluate the proposed project. ARPA-E may issue approximately 2-5 awards of this type, with an average award amount of $500,000.

- **Technology Development Project:** Awards that either range between $1 million and $10 million, have a period of performance longer than one year, or both are Technology Development Projects. These projects typically focus on early-stage prototypes of various technology concepts for which some kind of initial proof-of-concept component demonstration already exists. Applicants should submit concrete data that supports the success of the proposed project. ARPA-E may issue approximately 5-10 awards of this type, with an average award amount of $3 million.

ARPA-E may establish more than one budget period for each award and fund only the initial budget period(s). Applicants are not guaranteed funding beyond the initial budget period(s).

Before the expiration of the initial budget period(s), ARPA-E may perform a down-select among different recipients and provide additional funding only to a subset of recipients.

B. ARPA-E FUNDING AGREEMENTS

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

Congress directed ARPA-E to "establish and monitor project milestones, initiate research projects quickly, and just as quickly terminate or restructure projects if such milestones are not achieved."[45] Accordingly, ARPA-E has substantial involvement in the direction of every project, as described in Section II.C below.

1. COOPERATIVE AGREEMENTS

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients.[46]

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

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

2. FUNDING AGREEMENTS WITH FFRDCS, GOGOS, AND FEDERAL INSTRUMENTALITIES[47]

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

When a FFRDC is the *lead organization* for a Project Team, ARPA-E executes a funding agreement directly with the FFRDC and a single, separate Cooperative Agreement with the rest

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

of the Project Team. Notwithstanding the use of multiple agreements, the FFRDC is the lead organization for the entire project, including all work performed by the FFRDC and the rest of the Project Team.

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

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

3. TECHNOLOGY INVESTMENT AGREEMENTS

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

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

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

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

4. GRANTS

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

C. STATEMENT OF SUBSTANTIAL INVOLVEMENT

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

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

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

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

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

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

III. ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

1. INDIVIDUALS

U.S. citizens or permanent residents may apply for funding in their individual capacity as a Standalone Applicant,[48] as the lead for a Project Team,[49] or as a member of a Project Team.

2. DOMESTIC ENTITIES

For-profit entities, educational institutions, and nonprofits[50] that are incorporated in the United States, including U.S. territories, are eligible to apply for funding as a Standalone Applicant, as the lead organization for a Project Team, or as a member of a Project Team.

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

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

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

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

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

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

3. FOREIGN ENTITIES

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding as Standalone Applicants, as the lead organization for a Project Team, or as a member of a Project Team. All work by foreign entities must be performed by subsidiaries or affiliates incorporated in the United States (including U.S. territories). The Applicant may request a waiver of this requirement in the Business Assurances Form, which is submitted with the Full Application. Please refer to the Business Assurances Form for guidance on the content and form of the request.

4. CONSORTIUM ENTITIES

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

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

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

B. COST SHARING[51]

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

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

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

ARPA-E generally uses Cooperative Agreements to provide financial and other support to Prime Recipients (see Section II.B.1 of the FOA). Under a Cooperative Agreement, the Prime Recipient must provide at least 20% of the Total Project Cost[52] as cost share, except as provided in Sections III.B.2 or III.B.3 below.[53]

2. INCREASED COST SHARE REQUIREMENT

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

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

3. REDUCED COST SHARE REQUIREMENT

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

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

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

- Project Teams where domestic educational institutions, domestic nonprofits, and/or FFRDCs perform greater than or equal to 80%, but less than 100%, of the total work under the funding agreement (as measured by the Total Project Cost) are required to provide at least 10% of the Total Project Cost as cost share. However, any entity

[52] 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.
[53] Energy Policy Act of 2005, Pub.L. 109-58, sec. 988.

(such as a large business) receiving patent rights under a class waiver, or other patent waiver, that is part of a Project Team receiving this reduction must continue to meet the statutory minimum cost share requirement (20%) for its portion of the Total Project Cost.

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

4. LEGAL RESPONSIBILITY

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

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

5. COST SHARE ALLOCATION

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

6. COST SHARE TYPES AND ALLOWABILITY

Every cost share contribution must be allowable under the applicable Federal cost principles, as described in Section IV.G.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[54] to meet their cost share obligations under cooperative agreements. However, Project Teams may use IR&D funds to meet their cost share obligations under Technology investment Agreements.

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

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

Applicants may wish to refer to 10 C.F.R. parts 600 and 603 for additional guidance on cost sharing, specifically 10 C.F.R. §§ 600.30, 600.123, 600.224, 600.313, and 603.525-555.

7. COST SHARE CONTRIBUTIONS BY FFRDCS AND GOGOS

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

8. COST SHARE VERIFICATION

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

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

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.

C. OTHER

1. COMPLIANT CRITERIA

Concept Papers are deemed compliant if:

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

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

Full Applications are deemed compliant if:

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

ARPA-E will not review or consider noncompliant Full Applications, including Full Applications submitted through other means, Full Applications submitted after the applicable deadline, and

incomplete Full Applications. A Full Application is incomplete if it does not include required information and documents, such as Forms SF-424 and 424A. ARPA-E will not extend the submission deadline for Applicants that fail to submit required information and documents due to server/connection congestion.

Replies to Reviewer Comments are deemed compliant if:

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

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

2. RESPONSIVENESS CRITERIA

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

3. LIMITATION ON NUMBER OF APPLICATIONS

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

IV. APPLICATION AND SUBMISSION INFORMATION

A. APPLICATION PROCESS OVERVIEW

1. REGISTRATION IN ARPA-E eXCHANGE

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

2. CONCEPT PAPERS

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

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

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

3. FULL APPLICATIONS

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

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

4. REPLY TO REVIEWER COMMENTS

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

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

5. "DOWN-SELECT" PROCESS

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

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

6. SELECTION FOR AWARD NEGOTIATIONS

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

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

7. MANDATORY WEBINAR

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

B. APPLICATION FORMS

Required forms for Full Applications are available on ARPA-E eXCHANGE (https://arpa-e-foa.energy.gov), including the SF-424, Budget Justification Workbook/SF-424A, Business Assurances Form, and Other Sources of Funding Disclosure Form. Sample responses to the Other Sources of

Funding Disclosure Form and Business Assurances Form, and a sample Summary Slide, are also available on ARPA-E eXCHANGE. Applicants must use the templates available on ARPA-E eXCHANGE, including the template for the Concept Paper, the template for the Technical Volume of the Full Application, the Technical Milestones and Deliverables - Instructions and Examples, the template for the Summary Slide, the template for the Summary for Public Release, and the template for the Reply to Reviewer Comments.

C. CONTENT AND FORM OF CONCEPT PAPERS

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

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

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

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

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

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

SECTION	PAGE LIMIT	DESCRIPTION
Technology Description	2 pages maximum	• Applicants are required to describe succinctly: ○ The proposed technology, including its basic operating principles and how it is unique and innovative; ○ The proposed technology's target level of performance (Applicants should provide technical data or other support to show how the proposed target could be met); ○ The current state-of-the-art in the relevant field and application, including key shortcomings, limitations, and challenges; ○ How the proposed technology will overcome the shortcomings, limitations, and challenges in the relevant field and application; ○ The potential impact that the proposed project would have on the relevant field and application; ○ The key technical risks/issues associated with the proposed technology development plan; and ○ The impact that ARPA-E funding would have on the proposed project.
Addendum	2 pages maximum	• Applicants must state whether the proposed budget for their project falls into the first or second funding award type below: 1. Proof-of-Concept Seedling Project: $250,000 - $999,999.99 and period of performance of 12 months or less; or 2. Technology Development Project: $1 million - $10 million or a period of performance of greater than 12 months. • Applicants may provide graphs, charts, or other data to supplement their Technology Description. • Applicants are required to describe succinctly the qualifications, experience, and capabilities of the proposed Project Team, including: ○ Whether the Principal Investigator (PI) and Project Team have the skill and expertise needed to successfully execute the project plan; ○ Whether the Applicant has prior experience which demonstrates an ability to perform R&D tasks of similar risk and complexity; ○ Whether the Applicant has worked together with its teaming partners on prior projects or programs; and ○ Whether the Applicant has adequate access to equipment and facilities necessary to accomplish the R&D effort and/or clearly explain how it intends to obtain access to necessary equipment and facilities.

D. CONTENT AND FORM OF FULL APPLICATIONS

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.C of the FOA).

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

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.

Business Assurances Form	PDF	Requires the Applicant to 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, the Technology Transfer & Outreach (TT&O) spending requirement, and/or the U.S. manufacturing requirement. In addition, allows the Applicant to request the use of a Technology Investment Agreement. 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
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. • Clearly state the Technical Category (1A, 1B or 2) that is addressed by the proposed technology. If the proposed technology can meet the goals of the FOA combining the functions of more than one Technical Category in a single inseparable system, clearly state which Categories are being simultaneously addressed and how the overarching FOCUS FOA goals will be addressed.
R&D Tasks	1 page max.	• Describe succinctly: ○ The purpose of the proposed R&D project, ○ The underlying hypothesis(es)/technical concept(s) guiding the approach, and ○ A list of the tasks the research team will undertake and accomplish to achieve this purpose.
Block Diagram and Technology Costs	4 pages max.	• All applications: 1) A clear Block Diagram of the proposed technology, with estimated component efficiencies and losses indicated and, 2) A justification of estimated costs. (See Section I.H examples). Specifically: ○ For Category 1A Technology Development applications: ▪ A Block Diagram of the Category 1A hybrid solar converter, substantially following Figure 6. • A Cost Table for the hybrid solar converter, substantially following Table 4. ▪ A Block Diagram of the preferred system application of hybrid solar converter, substantially following Figure 7, with a clear indication of the System Subcategory (UE, SE or H). • For System Subcategories UE and SE, a Cost Table for the System Application, substantially following Table 7. • For System Subcategory H, an estimate of the system payback time, as discussed in Section I.E.2.1a. ○ For Category 1A Seedling applications ▪ A block diagram of a Category 1A hybrid solar converter in which the technology could be deployed, substantially following Figure 6. • A cost estimate for the technology component under development and an *optional* Cost Table for a hybrid solar converter in which it could be deployed ○ For applications addressing Category 1A and 2 simultaneously in a single inseparable system, one Block Diagram and one Cost Estimate Table combining relevant elements of Figures 6 and 7, and Tables 4 and 7.

R&D Strategy	20 pages max.	• Applicants are required 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. ○ Innovation and Impact – 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. ○ Feasibility – 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) ○ Performance Team – 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.[55] 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

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

		○ 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: ○ any prior projects, programs, and initiatives on which the Project Team has collaborated; ○ the roles of each Project Team member in the project, program, or initiative; ○ whether the project, program, or initiative was ultimately successful; and ○ 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: ○ The roles of each Project Team member; ○ Any critical handoffs/interdependencies between Project Team members; ○ 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: ○ The roles and the work to be performed by each PI and Key Participant; ○ Business agreements between the Applicant and each PI and Key Participant; and ○ 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 structure of the project as it pertains to the designation of multiple PIs. This plan should include: ○ Process for making decisions on scientific/technical direction; ○ Publication arrangements; ○ Intellectual property issues; ○ Communication plans; ○ Procedures for resolving conflicts; and ○ 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 April 1, 2013, 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).

- Unless a waiver is granted by the Contracting Officer, each Project Team must spend at least 5% of the Federal funding (i.e., the portion of the award that does not include the recipient's cost share) on Technology Transfer & Outreach (TT&O) activities to promote and further the development and deployment of ARPA-E-funded technologies. In

addition, Project Teams may not expend more than 5% of the Total Project Cost on TT&O activities without the prior approval of the Contracting Officer (see Section IV.G.8 of the FOA).

- All TT&O costs requested must be included in the Applicant's proposed budget and identified as TT&O costs in the Budget Justification Workbook/SF-424A with the costs being requested under the "Other" budget category. All budgeted activities must relate to achieving specific objectives, technical milestones and deliverables outlined in the Technical Milestones and Deliverables.

- For pricing purposes, assume a project start date of March 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: 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:

- 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;
- If the Applicant is a FFRDC, submit written authorization from the cognizant Federal agency; and
- If the Applicant is a DOE/NNSA FFRDC, submit a Field Work Proposal.

In addition, the Applicant may:

- Request authorization to perform some work overseas;
- Request a waiver of the TT&O spending requirement;
- Request the use of a Technology Investment Agreement instead of ARPA-E's Model Cooperative Agreement; and
- Request a modification or waiver of the U.S. Manufacturing requirement.

8. EIGHTH 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."[56] In accordance with its statutory mandate, ARPA-E requires the PI to complete 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;

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

- 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.C.1 of the FOA). ARPA-E will review and consider each compliant and responsive Full Application, even if no Reply is submitted or if the Reply is found to be noncompliant.

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

SECTION	PAGE LIMIT	DESCRIPTION
Text	2 pages maximum	• 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/arpa-e-site-page/post-award-guidance.

2. PRE-AWARD COSTS

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

Upon selection for award negotiations, Applicants may incur pre-award costs at their own risk, consistent with the requirements in 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 "Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf) 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. Because all patent costs are considered to be Technology Transfer & Outreach (TT&O) costs (see Section IV.G.8 of the FOA below), the waiver request is subject to review by the ARPA-E Program Director and approval by the Contracting Officer.

4. CONSTRUCTION

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

5. FOREIGN TRAVEL

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

6. PERFORMANCE OF WORK IN THE UNITED STATES

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

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

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

7. PURCHASE OF NEW EQUIPMENT

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

8. TECHNOLOGY TRANSFER AND OUTREACH

By law, ARPA-E is required to contribute a percentage of appropriated funds to Technology Transfer and Outreach (TT&O) activities. In order to meet this mandate every Project Team must spend at least 5% of the Federal funding (i.e., the portion of the award that does not include the recipient's cost share) provided by ARPA-E on TT&O activities to promote and further the development and deployment of ARPA-E-funded technologies. Project Teams may not expend more than 5% of the Total Project Cost on TT&O activities without the prior approval of the Contracting Officer. Project Teams must also seek a waiver from the Contracting Officer to spend less than the minimum 5% TT&O expenditure requirement.

All TT&O expenditures are subject to the applicable Federal cost principles, as described in Section IV.G.1 of the FOA. Examples of TT&O expenditures are as follows:

- Documented travel and registration for the ARPA-E Energy Innovation Summit and other energy-related conferences and events;
- Documented travel to meet with potential suppliers, partners, or customers;
- Documented work by salaried or contract personnel to develop technology-to-market models or plans;
- Documented costs of acquiring industry-accepted market research reports; and

- Approved patent costs.

ARPA-E will not reimburse the following types of TT&O expenditures, which do not comply with Federal cost principles.

- Meals or entertainment;
- Gifts to potential suppliers, partners, or customers;
- TT&O activities that do not relate to the ARPA-E-funded technologies or to at least one objective in the Technical Milestones and Deliverables;
- Undocumented TT&O activities; and
- TT&O activities unrelated and/or unallocable to the subject award.

Applicants may seek a waiver of the TT&O requirement by including an explicit request in the Business Assurances Form. Please refer to the Business Assurances Form for guidance on the content and form of the waiver request. ARPA-E Program Directors may waive or modify the TT&O requirement, as appropriate.

For information regarding incorporation of TT&O costs into budget documentation, see Section IV.D.3 of the FOA.

Please refer to the "Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf) for additional guidance on TT&O requirements.

9. 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.[57]

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

- An officer or employee of any Federal agency,

[57] 18 U.S.C. § 1913.

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

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

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

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

Applicants should not wait until the last minute to begin the submission process. During the final hours before the submission deadline, Applicants may experience server/connection congestion that prevents them from completing the necessary steps in ARPA-E eXCHANGE to

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

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

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

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

V. APPLICATION REVIEW INFORMATION

A. CRITERIA

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

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

1. CRITERIA FOR CONCEPT PAPERS

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

- The extent to which the proposed quantitative material and/or technology metrics demonstrate the potential for a transformational and disruptive (not incremental) advancement in one or more of the Categories of Interest described in Section 1.E toward technologies meeting the metrics in Section 1.F.

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

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

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

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

- The feasibility of the proposed work;

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

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

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

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

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

2. CRITERIA FOR FULL APPLICATIONS

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;

- 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%

3. 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 Applicants to encourage to submit Full Applications and which Full Applications to select for award negotiations:

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

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

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

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

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

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

2. ARPA-E REVIEWERS

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

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

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

3. ARPA-E SUPPORT CONTRACTOR

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

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

C. ANTICIPATED ANNOUNCEMENT AND AWARD DATES

ARPA-E expects to announce selections for negotiations in mid-January, 2014 and to execute funding agreements in April, 2014.

VI. AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

1. REJECTED SUBMISSIONS

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

2. CONCEPT PAPER NOTIFICATIONS

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

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

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

3. FULL APPLICATION NOTIFICATIONS

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

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

a. SUCCESSFUL APPLICANTS

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

Please refer to Section IV.G.2 of the FOA for guidance on pre-award costs. Please also refer to the "Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf) for guidance on the award negotiation process.

b. POSTPONED SELECTION DETERMINATIONS

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

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

c. UNSUCCESSFUL APPLICANTS

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

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

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

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

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

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

By law, Prime Recipients are also required to register with the Federal Funding Accountability and Transparency Act Subaward Reporting System (FSRS) at https://www.fsrs.gov/.[58] Prime Recipients are required to report to FSRS the names and total compensation of each of the Prime Recipient's five most highly compensated executives and the names and total compensation of each Subrecipient's five most highly compensated executives. Please refer to https://www.fsrs.gov/ for guidance on reporting requirements.

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

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

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

2. National Policy Assurances

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

3. Proof of Cost Share Commitment and Allowability

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

The Prime Recipient is also required to provide cost share commitment letters from Subrecipients or third parties that are providing cost share, whether cash or in-kind. Each Subrecipient or third party that is contributing cost share must provide a letter on appropriate letterhead that is signed by an authorized corporate representative. Please refer to the "Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf) for guidance on the contents of cost share commitment letters.

4. Cost Share Payments[59]

All proposed cost share contributions must be reviewed in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

ARPA-E requires Prime Recipients to contribute the cost share amount incrementally over the life of the funding agreement.[60] Specifically, every Prime Recipient is required to contribute, at a minimum, the cost share percentage of total expenditures incurred during every billing period. For example, a Prime Recipient is required to contribute at least 31% of the total expenditures incurred during every billing period if the funding agreement states that the cost share percentage 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.

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

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 "Applicants' Guide to ARPA-E Award Negotiations" (http://arpa-e.energy.gov/sites/default/files/documents/files/Applicants%20Guide%20to%20ARPA-E%20Award%20Negotiations%20Nov2012.pdf) for additional guidance on cost share payment requirements.

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

5. ENVIRONMENTAL IMPACT QUESTIONNAIRE

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

To facilitate and expedite ARPA-E's environmental review, Prime Recipients are required to complete an Environmental Impact Questionnaire during award negotiations. This form is available on ARPA-E eXCHANGE at https://arpa-e-foa.energy.gov. The Environmental Impact Questionnaire is due within 21 calendar days of the selection announcement.

6. TECHNOLOGY-TO-MARKET PLAN

During award negotiations, Prime Recipients are required to negotiate and submit an initial Technology-to-Market Plan to the ARPA-E Program Director, and obtain the ARPA-E Program Director's approval prior to the execution of the award. Prime Recipients must show how budgeted Technology Transfer and Outreach (TT&O) costs relate to furthering elements of the Technology-to-Market Plan. During the project period, Prime Recipients are required to provide regular updates on the initial Technology-to-Market plan and report on implementation of Technology-to-Market activities. Prime Recipients may be required to perform other actions to further the commercialization of their respective technologies.

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

7. INTELLECTUAL PROPERTY MANAGEMENT PLAN

ARPA-E requires every Project Team to negotiate and establish an Intellectual Property Management Plan for the management and disposition of intellectual property arising from the project. The Prime Recipient must submit a completed and signed Intellectual Property Management plan to ARPA-E within six weeks of the effective date of the ARPA-E funding agreement. All Intellectual Property Management Plans are subject to the terms and conditions of the ARPA-E funding agreement and its intellectual property provisions, and applicable Federal laws, regulations, and policies, all of which take precedence over the terms of Intellectual Property Management Plans.

ARPA-E has developed a template for Intellectual Property Management Plans (http://arpa-e.energy.gov/FundingAgreements/Overview.aspx) so as to facilitate and expedite negotiations between Project Team members. ARPA-E does not mandate the use of this template. ARPA-E and DOE do not make any warranty (express or implied) or assume any liability or responsibility for the accuracy, completeness, or usefulness of the template. ARPA-E and DOE strongly encourage Project Teams to consult independent legal counsel before using the template.

8. U.S. MANUFACTURING REQUIREMENT

ARPA-E requires products embodying or produced through the use of subject inventions (i.e., inventions conceived or first actually reduced to practice under ARPA-E funding agreements) to be substantially manufactured in the United States by Project Teams and their licensees, as described below. The Applicant may request a modification or waiver of the U.S. Manufacturing Requirement 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).[61] This requirement does not apply to products that are manufactured for use or sale outside the U.S. A.

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

[22] 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).

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

b. LARGE BUSINESSES AND FOREIGN ENTITIES

Large businesses and foreign entities that are Prime Recipients or Subrecipients under ARPA-E funding agreements are required to substantially manufacture the following products in the United States: (1) products embodying subject inventions, and (2) products produced through the use of subject invention(s).[62] This requirement applies to products that are manufactured for use or sale in the United States and outside the United States.

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

c. EDUCATIONAL INSTITUTIONS AND NONPROFITS

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

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

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

d. FFRDCs and State and Local Government Entities

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

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

C. 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 (http://arpa-e.energy.gov/FundingAgreements/CooperativeAgreements.aspx).

VII. AGENCY CONTACTS

A. COMMUNICATIONS WITH ARPA-E

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

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

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

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

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

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

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

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

B. DEBRIEFINGS

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

VIII. OTHER INFORMATION

A. FOAS AND FOA MODIFICATIONS

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

B. OBLIGATION OF PUBLIC FUNDS

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

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

C. REQUIREMENT FOR FULL AND COMPLETE DISCLOSURE

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

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

D. RETENTION OF SUBMISSIONS

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

E. MARKING OF CONFIDENTIAL INFORMATION

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

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

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

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

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

F. TITLE TO SUBJECT INVENTIONS

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

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

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

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

G. GOVERNMENT RIGHTS IN SUBJECT INVENTIONS

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

1. GOVERNMENT USE LICENSE

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

2. MARCH-IN RIGHTS

The U.S. Government retains march-in rights with respect to all subject inventions. Through "march-in rights," the Government may require a Prime Recipient or Subrecipient who has

elected to retain title to a subject invention (or their assignees or exclusive licensees), to grant a license for use of the invention. In addition, the Government may grant licenses for use of the subject invention when Prime Recipients, Subrecipients, or their assignees and exclusive licensees refuse to do so.

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

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

H. RIGHTS IN TECHNICAL DATA

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

- Background or "Limited Rights Data": The U.S. Government will not normally require delivery of technical data developed solely at private expense prior to issuance of an award, except as necessary to monitor technical progress and evaluate the potential of proposed technologies to reach specific technical and cost metrics.
- Generated Data: The U.S. Government normally retains very broad rights in technical data produced under Government financial assistance awards, including the right to distribute to the public. However, pursuant to special statutory authority, certain categories of data generated under ARPA-E awards may be protected from public disclosure for up to five years. Such data should be clearly marked as described in Section VIII.E of the FOA. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

I. PROTECTED PERSONALLY IDENTIFIABLE INFORMATION

Applicants may not include any Protected Personally Identifiable Information (Protected PII) in their submissions to ARPA-E. Protected PII is defined as data that, if compromised, could cause

harm to an individual such as identity theft. Listed below are examples of Protected PII that Applicants must not include in their submissions.

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

J. ANNUAL COMPLIANCE AUDITS FOR FOR-PROFIT ENTITIES

If a for-profit entity is the Prime Recipient, 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://management.energy.gov/business_doe/business_forms.htm.

IX. GLOSSARY

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

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

ARPA-E: Advanced Research Projects Agency-Energy.

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

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

DOE: U.S. Department of Energy.

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

FFRDCs: Federally Funded Research and Development Centers.

FOA: Funding Opportunity Announcement.

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

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

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

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

PI: Principal Investigator.

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

R&D: Research and development.

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

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

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

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

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