Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy (EERE)

Solar Energy Technologies Office Fiscal Year 2019 Funding Program

Funding Opportunity Announcement (FOA) Number: DE-FOA-0002064
FOA Type: Initial
CFDA Number: 81.087

FOA Issue Date:	March 26, 2019
Submission Deadline for Mandatory Letter of Intent (LOI):	May 7, 2019, 5:00 pm ET
Informational Webinars:	Five webinars will be scheduled (one per topic area). Webinar information will be available in EERE Exchange at https://eere-Exchange.energy.gov.
Submission Deadline for Concept Papers: • Applicants must submit a Concept Paper by 5:00pm ET on the due date listed to be eligible to submit a Full Application. • Topic Area 1.2 applicants must resubmit their LOI again as a Concept Paper by the Concept Paper deadline listed to clear an administrative software restriction of EERE Exchange.	May 14, 2019, 5:00 pm ET
Submission Deadline for Full Applications and SIPS Applications:	July 25, 2019, 5:00 pm ET
Expected Submission Deadline for Replies to Reviewer Comments:	September 6, 2019, 5:00 pm ET
Expected Date for EERE Selection Notifications:	November 2019
Expected Timeframe for Award Negotiations:	November 2019-February 2020

- Applicants must submit a Letter of Intent (LOI) and Concept Paper by 5:00 pm ET on the due date listed above to be eligible to submit a Full Application.
- To apply to this Funding Opportunity Announcement (FOA), applicants must register with and submit application materials through EERE Exchange at https://eere-Exchange.energy.gov, EERE's online application portal.
- Applicants must designate primary and backup points-of-contact in EERE Exchange with whom EERE will communicate to conduct award negotiations. If an application is

selected for award negotiations, it is not a commitment to issue an award. It is imperative that the applicant/selectee be responsive during award negotiations and meet negotiation deadlines. Failure to do so may result in cancelation of further award negotiations and rescission of the selection.

Table of Contents

I. Funding Opportunity Description

A. Background and Context

i. Background and Purpose

This FOA is being issued by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Solar Energy Technologies Office (SETO). This section describes the overall goals of SETO and the type of projects that are being solicited for funding support through this FOA.

In the past 40 years, solar energy has grown from a niche technology powering satellites in space to a technology that powers homes and businesses in every state. According to the U.S. Energy Information Administration (EIA), solar supplied nearly 2.5% of U.S. electricity demand in the first 11 months of 2018,[1] and in some states, solar represented up to 15% of total annual electricity generation.[2] There are nearly 2 million solar installations in increasingly diverse climates, policy environments, and commercial markets across the country.[3] Some of America's biggest companies, including Walmart, Apple, Target, and Amazon, lead corporate adoption of solar and help mobilize demand for solar in new regions.

This growth has been driven in part by a dramatic decline in costs, especially in the past decade. Since 2010, solar costs have declined 70% to 80%, making solar one of the most economical ways to add new electricity generation to the grid. From 2011 to 2018, cumulative installed solar power capacity increased from just 1.2 gigawatts (GW) to 60 GW for utility-scale, commercial, and residential solar systems in the United States.[4] The EIA estimates that in 2019, 18% of new utility-scale capacity additions will come from solar energy[5] and that solar will grow to account for 5% of U.S. electricity by 2030.[6] If the price of solar electricity and/or energy storage declines more rapidly than projected, that percentage could be much larger.[7]

---

[1] U.S. Energy Information Administration. *Electric Power Monthly with Data for November 2018*. https://www.eia.gov/electricity/monthly/current_month/epm.pdf. January 2019.
[2] California Independent System Operator. *Monthly Renewables Performance Report.* http://www.caiso.com/Documents/MonthlyRenewablesPerformanceReport-May2018.html. May 2018.
[3] Solar Energy Industries Association. *Solar Means Business Report.* https://www.seia.org/research-resources/solar-means-business-2017. 2017.
[4] Solar Energy Industries Association. http://www.seia.org/.
[5] U.S. Energy Information Administration. "Today in Energy." https://www.eia.gov/todayinenergy/detail.php?id=37952. January 10, 2019.
[6] U.S. Energy Information Administration. *International Energy Outlook 2017*. https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf.
[7] U.S. Department of Energy Solar Energy Technologies Office. SunShot 2030. https://www.energy.gov/eere/solar/sunshot-2030.

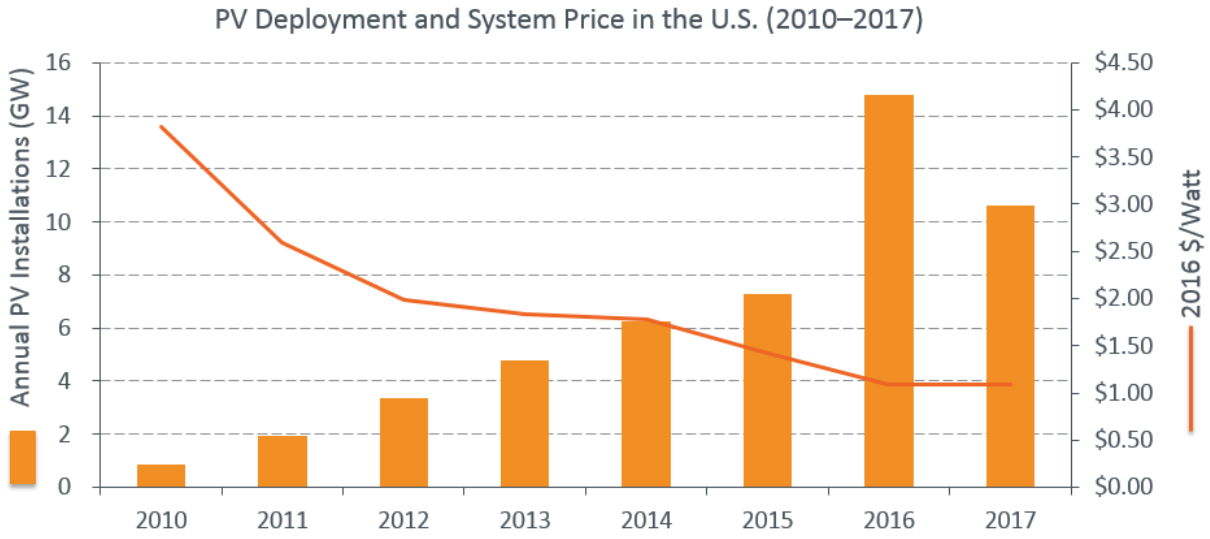

Figure 1. *The price per watt of solar photovoltaics and annual deployment*[8]

Ensuring that more Americans can benefit from the declining costs of solar is one of SETO's primary goals, which support early-stage research, development, and demonstration of solar technologies. Since 2011, the solar office has been working toward the SunShot cost goals to make solar electricity price-competitive with conventional utility sources by 2020.[9] Those technology investments have lowered costs across the solar value chain, enhancing business growth and reducing red tape. While this work has assisted American leadership in solar innovation and lowered the cost of solar, more work needs to be done to reduce energy costs for all Americans.

In 2017, SETO announced that the industry had achieved the SunShot 2020 utility-scale goal, three years early. The achievement of this goal and increased solar deployment have created a need for research well beyond the challenge of component costs. At the same time, grid modernization efforts, deployment of energy storage, digitization of the grid, and concerns about cybersecurity have changed the energy landscape. Integrating solar with long-term energy storage, improving operational tools for solar on the grid, and enhancing photovoltaic (PV) systems' cybersecurity are areas of growing priority for SETO. These areas represent ways that solar technologies can play a greater role in ensuring that energy is readily available and secure across the country.

[8] National Renewable Energy Laboratory. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016;* GTM Research and Solar Energy Industries Association, *U.S. Solar Market Insight Report: 2016 YIR.*

[9] U.S. Department of Energy Solar Energy Technologies Office. *SunShot Vision Study*. https://www.energy.gov/sites/prod/files/2014/01/f7/47927.pdf. 2012.

In order to prepare for the rapid increase in solar generating capacity and allow businesses to operate most efficiently, the office also works to both remove deployment barriers associated with excessive red tape and scale pathways to commercialization. These efforts address the non-hardware costs to deploy and integrate more solar onto the grid. SETO's efforts make unbiased, technical information available to key stakeholders and support the development of new products that can solve marketplace challenges.

ii. Technology Space and Strategic Goals

SETO works across the solar energy technology spectrum with the goal of improving the affordability, reliability, and performance of solar technologies on the grid. Solar energy technologies fall into two broad categories: PV technologies that directly convert sunlight into electricity and concentrating solar-thermal power (CSP) technologies that convert sunlight to heat, which can be used to generate electricity or provide other energy services.

These technologies depend on a suite of tools that enable the integration of solar onto the grid. SETO's systems integration research covers a variety of topics, including operational tools to better integrate and control distributed resources, sensors that provide increased visibility to systems connected to the grid, and power electronics through which solar energy flows before it is used. As a greater percentage of the nation's energy comes from solar, these tools become increasingly important to maintaining a reliable and resilient grid.

The adoption of power electronics, sensors, and communications tools within solar and the electric industry more broadly enable system operators to identify and manage the flow and quality of electricity on the grid. However, the need for data sharing between the PV system, operational tools, and the electric grid has led to increased vulnerability to cyberattack. The solar office works to boost PV resilience to such threats through a wide range of approaches, incorporating technology development and industry partnerships, to ensure that the grid is secure.

SETO works to ensure that the early-stage technologies developed through federal funding are relevant to the private sector. This is accomplished through partnerships to facilitate the exchange of information between industry and research communities, as well as across scientific disciplines. The solar office also funds research in products that have the potential to be rapidly commercialized but are too risky for private investment. In all, these efforts help to support American leadership in the solar industry.

Solar energy adoption faces significant challenges beyond technology gaps. With more than 18,000 authorities having jurisdiction and 3,300 utilities across the country, navigating diverse regulations and processes is complex. The office has

funded several efforts to streamline processes across the country. As new markets tackle these challenges, the development and implementation of uniform practices will reduce the regulatory burden on businesses leading to lower operating costs.

SETO operates in coordination with other offices across the DOE. The Grid Modernization Initiative,[10] a program that works closely with the Office of Electricity and other DOE offices to create the advanced grid of the future, is a key partner in the solar office's grid integration efforts. These research activities are aligned with the major technology areas identified in the Grid Modernization Multi-Year Program Plan,[11] including grid resilience, energy storage, sensors and measurements, and cybersecurity. The solar office also collaborates with the Building Technologies Office, the Vehicles Technologies Office, and other EERE offices through the Beyond Batteries initiative to develop new technologies and analytical tools that improve grid reliability through increased flexibility and grid services, balancing renewable generation, load, and alternative storage technologies. Finally, SETO's cybersecurity research is coordinated with the Office of Cybersecurity, Energy Security, and Emergency Response and is aligned with the EERE cybersecurity vision and multi-year plan goals.

2030 Cost Targets

SETO works to achieve 2030 SunShot targets that reduce the cost of solar by an additional 40% to 70% beyond 2018 costs. Achieving these targets would make solar one of the most affordable sources of new electricity generation.[12] The targets for the unsubsidized, levelized cost of energy (LCOE) at the point of grid connection are:

- $0.03 per kilowatt-hour (kWh) for utility-scale PV
- $0.04 per kWh for commercial rooftop PV
- $0.05 per kWh for residential rooftop PV
- $0.05 per kWh for CSP with thermal energy storage

[10] U.S. Department of Energy Grid Modernization Initiative. https://www.energy.gov/grid-modernization-initiative.
[11] U.S. Department of Energy Grid Modernization Multiyear Program Plan. https://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp.
[12] U.S. Department of Energy. *The SunShot Initiative's 2030 Goal: 3¢ per Kilowatt Hour for Solar Electricity.* https://www.energy.gov/sites/prod/files/2016/12/f34/SunShot%202030%20Fact%20Sheet-12_16.pdf. 2016.

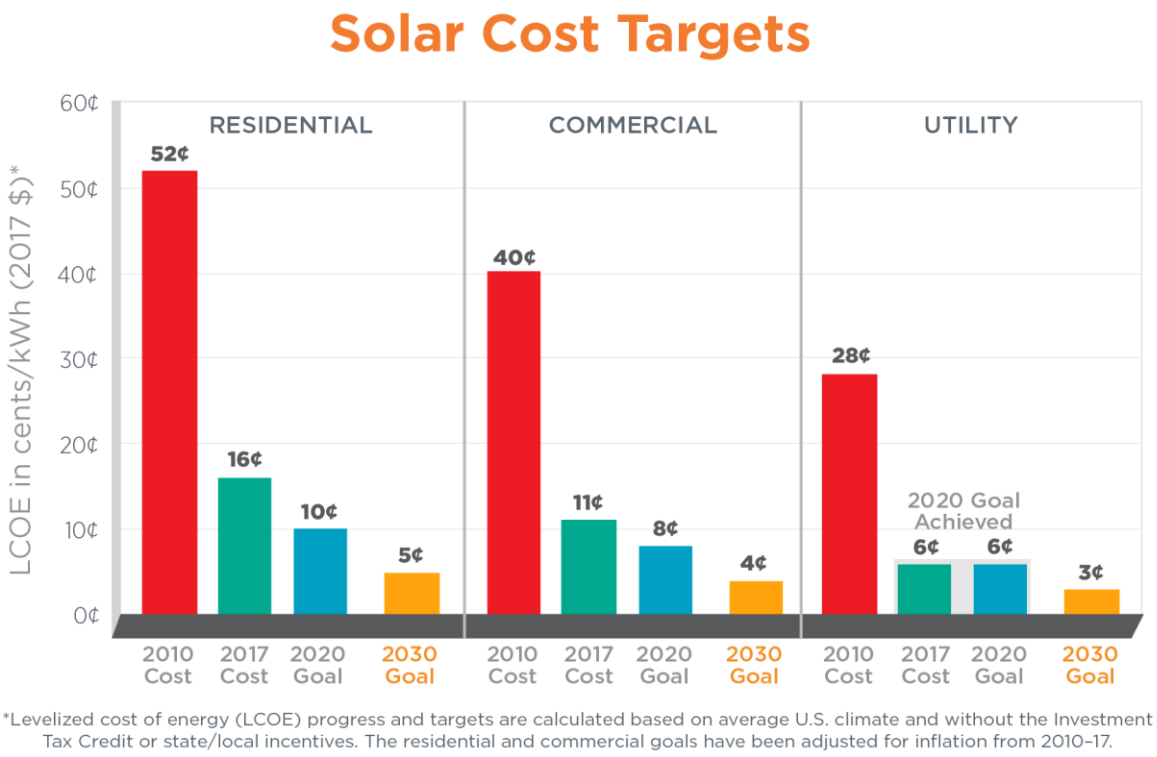

Figure 2. *2030 PV LCOE cost targets*

The 2030 PV LCOE targets are defined for an area that has average U.S. climate. For example, a $0.03 LCOE for utility-scale would translate to $0.02 to $0.04 LCOE across the continental United States because of differences between locations in the amount of sunlight and in temperature, snow accumulation, and wind speed.

Although these targets are aggressive, there are multiple realistic pathways toward achieving them. All pathways require significant improvements across the office's research areas, as greater progress in one area can allow for moderate change in others. These interdependencies and trade-offs among cost- and performance-improvement factors create numerous technology-development opportunities.

Priority Research Areas

Achieving SETO's priorities across the solar energy technology landscape requires sustained, multifaceted innovation. With this FOA, the office intends to fund high-impact, early-stage research in the following areas:

Topic Area 1: Photovoltaics Research and Development

This topic will support several applied research collaborations to tackle key challenges in commercially available technologies and to invest in new materials that can lower the cost of PV-generated electricity. It will look at system-level

opportunities that can increase the amount of energy produced by a PV array over its lifetime and lower the costs of manufacturing and deploying solar systems. In addition, it will fund several high-risk, early-stage projects to seed new ideas for continued research. By taking a collaborative approach, advances from these projects will ensure that the U.S. solar industry continues to be on the cutting edge of PV technology development.

Topic Area 2: Concentrating Solar-Thermal Power Research and Development

This topic will support the development of new thermal storage technologies that will make solar energy available on demand. It will also support the development of advanced manufacturing and autonomous operational technologies to reduce the cost of CSP. CSP's inherent ability to incorporate storage makes this renewable technology more useful to grid operators. The improvements targeted by this research aim to increase the performance of CSP plants, encourage the commercialization of new CSP technologies, and support the development of an agile, U.S.-based CSP manufacturing sector.

Topic Area 3: Balance of Systems Soft Costs Reduction

This topic will support several collaborative partnerships with industry to reduce regulatory and financing burdens that increase costs for solar developers and consumers. Research will be focused on enabling the country's new and developing solar markets to tackle financing and permitting issues for solar and solar-plus-storage systems, and implementing best practices and lessons learned from SETO's previous research. The work will also examine cybersecurity threats and potential responses to them with an eye toward developing strategic plans and other decision-making tools that can advance cybersecurity solutions in anticipation of potential technical, policy, and regulatory risks. These efforts aim to increase solar energy affordability for more Americans and expand the solar market across the country.

Topic Area 4: Innovations in Manufacturing: Hardware Incubator
This topic will support for-profit companies developing early-stage product ideas that have both a clear pathway to reducing solar electricity costs and the potential for rapid commercialization. These projects should be well positioned to attract follow-on investment in the transition to becoming self-supporting. In particular, research will focus on the development of innovative and impactful technologies that support a strong U.S. solar manufacturing sector.

Topic Area 5: Advanced Solar Systems Integration Technologies
This topic will support the development of technologies that will ease the integration of solar energy onto the nation's electricity grid, especially in areas where solar could account for a high percentage of the electricity supply. Research will focus on how distributed generation can help provide additional value to system operators while increasing coordination and control of power electronics technologies. These technologies will improve the energy sector's ability to respond to extreme events, like fires and cyberattacks, and rapidly restore service if interrupted.

Projects funded by SETO are expected to produce high-impact outcomes with a view toward commercialization and wide dissemination, including publication of the results in high-visibility, high-impact, peer-reviewed journals.

Potential applicants interested specifically in cybersecurity or manufacturing should take note of the following:

- Applicants who wish to pursue cybersecurity projects that develop collaborative partnerships to address future regulatory burdens should apply to Topic Area 3.1: Collaborative Partnerships to Address Regulatory Burdens. Applicants who wish to pursue projects that tackle technical challenges related to cybersecurity should apply to Topic Area 5.3: Advanced PV Controls and Cybersecurity.
- Applicants who wish to pursue manufacturing innovations should consider Topic Area 1.1: Photovoltaics Research Collaborations, Commercializing TES, Topic Area 2.2: Materials and Manufacturing, and Topic Area 4: Innovations in Manufacturing: Hardware Incubator.

Office-Wide Funding Strategy
This document integrates the funding opportunities for all of SETO. The next section of this document, Topic Areas , is organized by program area, and potential applicants should go directly to their specific areas of interest.

B. Topic Areas

i. Topic Area 1: Photovoltaics Research and Development

The SETO PV research and development program funds technology dedicated to fully realizing the potential of PV power generation to provide affordable and reliable electricity for U.S. consumers and businesses. In pursuit of this goal, SETO has set cost targets of $0.03, $0.04, and $0.05 per kWh for PV-generated electricity from utility-scale, commercial, and residential systems, respectively, to be met by 2030 without subsidies in regions of the U.S. with moderate sunlight.[13] In order to achieve the deep cost reductions necessary to meet these targets, the PV research and development program supports research projects dedicated to increasing performance, reducing material and manufacturing costs, and improving the reliability of PV cells, modules, and systems.

One potential pathway to reducing costs to the $0.03 per kWh utility-scale 2030 target is shown in **Error! Reference source not found.**, below. This pathway was developed to include a balance of cell, module, and system technology advances that contribute to a reduced overall LCOE. While this example features specific improvements in module price, service lifetime, operations and maintenance (O&M), and soft costs, there are numerous possible alternate scenarios that can achieve the 2030 goals.

[13] Achieving the 2030 cost targets would result in even lower costs for PV-generated electricity in areas of the nation with higher solar irradiance.

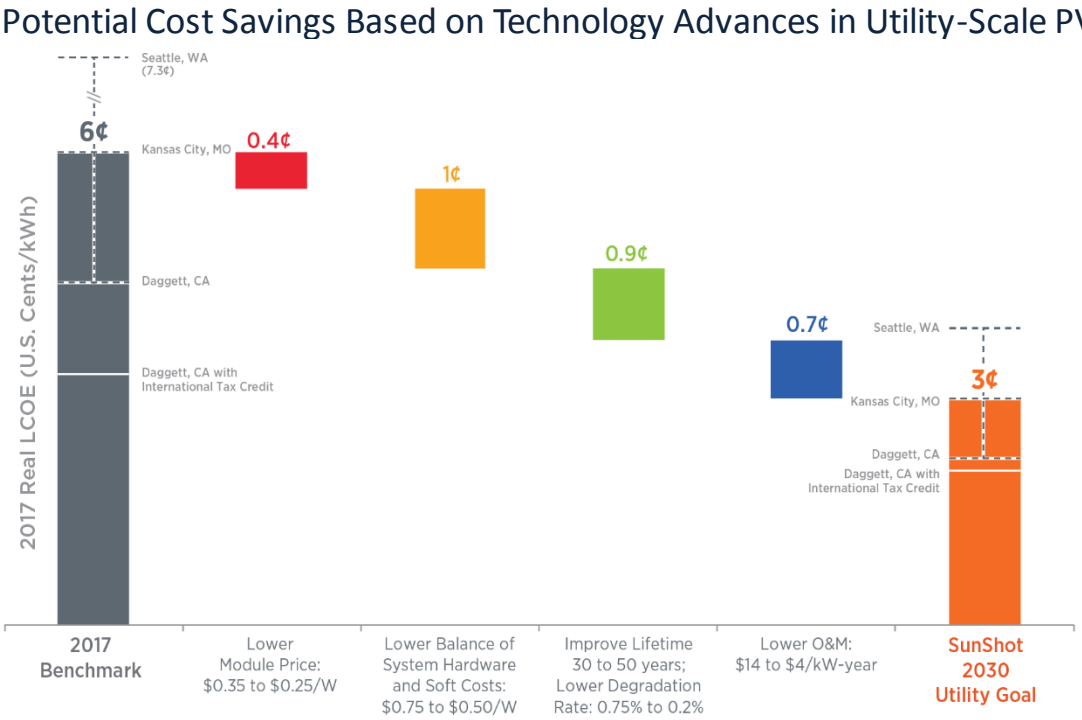

Figure 3. *Waterfall chart showing one possible pathway to achieving an unsubsidized LCOE of 3¢/kWh for a typical utility-scale PV project in the United States*

Figure 4, below, shows a recent cost analysis that breaks down the approximate price of construction for new residential- and utility-scale PV systems. Continued advancements in module manufacturing technologies and increases in the overall size, scale, and operational efficiency of the cell and module manufacturing supply chain have resulted in considerable reductions in PV module costs. A system-level cost breakdown shows that opportunities exist to reduce costs by improving racking, wiring, and power electronics, or by increasing cell and module efficiency to reduce the number of system-level components needed to support a given system size.

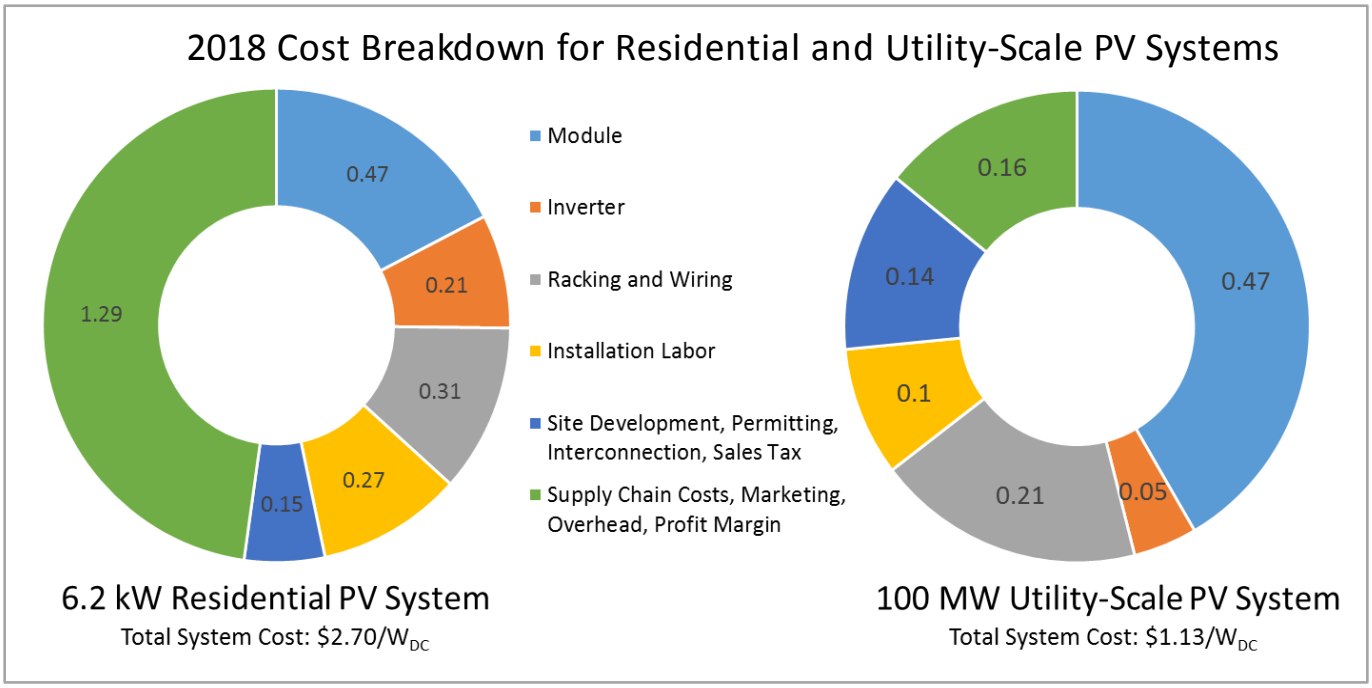

Figure 4. *PV system-cost breakdowns for 2018, including PV modules, system racking, electrical components, and other costs associated with system construction and commissioning. This data has been adapted from the National Renewable Energy Laboratory's "U.S. Solar Photovoltaic Cost Benchmark: Q1 2018."[14] All cost units are in dollars per watt of direct-current capacity ($/W$_{DC}$), with the utility-scale cost breakdown based on the use of single axis tracking.*

Maximizing performance and reliability while decreasing the cost of new PV arrays will likely require improvements across all system hardware and components. Optimizing the design and construction of PV systems to maximize annual energy yield without increasing costs can lower the LCOE. Research efforts to maximize energy yield, or how much electricity a PV system will generate in the field over the course of its service lifetime, include reducing the detrimental impact of soiling, module operating temperature, partial shading, and other sources of power loss during system operation. Technology approaches that accelerate the design and construction of PV systems also help reduce the cost of PV-generated electricity.

There is also a need for increased data and improved analysis methods for performance monitoring and failure detection. Software and hardware solutions that provide more precise energy-production estimates and streamline operations by monitoring PV system components can inform cell and module research, decrease performance risk, and increase the value of PV arrays over their lifetime.

[14] National Renewable Energy Laboratory. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018*. https://www.nrel.gov/docs/fy19osti/72399.pdf. November 2018.

Figure 5, below, summarizes some of the major technology advances that have allowed for continuous cost reductions in crystalline silicon (c-Si) PV-module manufacturing over the past decade, and offers a vision of potential future cost reductions should research and development advances continue to be implemented at production scale. At the cell level, silicon, cadmium telluride, and other absorber technologies face unique technical challenges to closing the gap between their theoretical efficiency limits and current lab and commercial-scale performance records. Beneath these differences, however, increasing the quality and performance of any cell technology generally requires gaining precise control of each material, interface, and power-loss mechanism within the device. This shared foundation offers an opportunity for collaborative efforts that blur the lines between absorber-specific technologies, and that potentially allow for the transfer of ideas and expertise between historically separate branches of the PV research community.

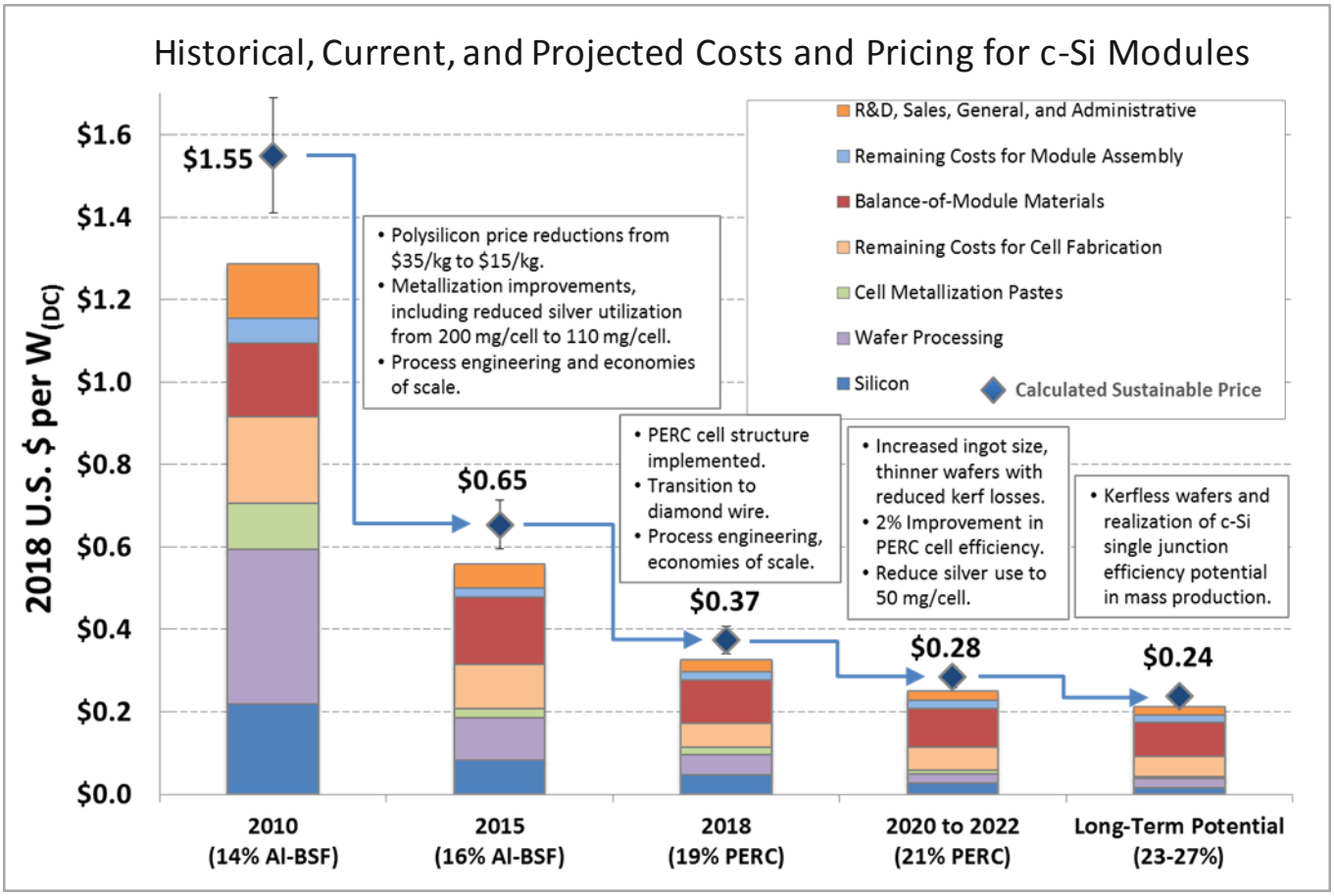

Figure 5. *Historic and one set of future projected prices and production costs for silicon PV modules showing cost reductions from the use of aluminum back surface field (Al-BSF) and passivated emitter and rear cell (PERC) architectures. Also shows*

technology improvements that have impacted PV-module manufacturing costs in the past 10 years and potential improvements that may contribute to future cost reductions. Image adapted from the National Renewable Energy Laboratory Strategic Energy Analysis Center. [15]

As commercial PV modules become more sophisticated, reliable, and efficient, the research community must be increasingly attentive to the state of the industry's leading edge to ensure their PV cell and module technologies remain relevant. This funding opportunity intends to bring together researchers from universities, companies, and national labs to form collaborative research teams with access to a high-performance baseline technology and clear visibility into the present and future commercial state of the art.

The PV Research and Development section of this funding opportunity includes two topic areas:

- Large research projects that bring multiple institutions together to work toward a focused goal are solicited in Topic Area 1.1: Photovoltaics Research Collaborations
- Smaller, one-year projects intended to provide a foothold for new technologies or areas of study are solicited in Topic Area 1.2: Small Innovative Projects in Solar (SIPS)

1. Topic Area 1.1: Photovoltaics Research Collaborations

This topic area solicits applications for projects that will bring together teams of researchers from multiple institutions and/or companies to address vital problems that limit the performance, cost, and reliability of current PV technologies. Projects are expected to receive up to $1.67 million per year and will be funded for three years. Some of these initiatives will continue after that, up to a total of five years, based on the results of a competitive down-selection and a second merit-review process during the third year. As such, applications to this area should provide a detailed work plan for the first three years of effort, with indicative plans for five-year targets that could be pursued during the fourth and fifth years. (See Cost Sharing for more information.)

Applications to this topic area should identify the areas of research that the proposed project will address, and explain how the project team will be able to develop technologies that surpass the performance, cost, and reliability of the best technologies currently available in their proposed research area. Each proposal is expected to have a project team that will:

[15] National Renewable Energy Laboratory Crystalline Silicon Photovoltaic Module Manufacturing Costs and Sustainable Pricing: 1H 2018 Benchmark and Cost Reduction Roadmap. https://www.nrel.gov/docs/fy19osti/72134.pdf. February 2019.

(1) Have immediate access to high-quality fabrication, modeling, or data-acquisition capabilities at the start of the project
(2) Have access to research-scale prototyping and testing capabilities where new ideas can be rapidly screened, tested, iterated, and implemented
(3) Be capable of directly influencing the industrial state of the art through regular contact with leading stakeholders in the proposed area of research. Examples of stakeholders that are central to the various segments of the PV supply chain are provided below in Figure 6.

Each application under Topic Area 1.1 should clearly explain which areas of research and stages of the supply chain will be targeted for improvement by the proposed effort. Each team should be capable of coordinating and enhancing nationwide research and development efforts within their proposed areas of work. The teams should be prepared to continuously identify and engage with relevant stakeholders throughout the project, and regularly solicit feedback on any newly developed technologies from potential end users and customers.

Key Stakeholders, by Research Area and Supply Chain Segment

		Supply Chain Segment		
		Cell	Module	System
Research Area	Material and Design Improvements	Equipment and material suppliers, cell and module manufacturing firms, manufacturing support and consulting firms, automation and quality control specialists		System developers, system owners, racking and electronics suppliers, O&M providers, system auditors, financiers and insurance firms, EPC specialists and engineering firms
	Hardware Fabrication and Deployment			
	Model Development, Material Characterization, and Analysis	Universities and research institutes, cell and module manufacturers, equipment and material suppliers		Engineering firms, system auditors, system developers, EPC specialists, system monitoring specialists
	Reliability and Bankability Studies	System owners, engineering firms, universities and research institutes, system monitoring specialists, O&M providers, system auditors, financiers and insurance firms, EPC specialists, system developers		

Figure 6. *Examples of key stakeholders that should be considered when addressing various research and development areas and segments of the PV supply chain*

Areas of Interest for Applications to Topic Area 1.1

The following pages contain a list of areas of research that are of particular interest for the development of Photovoltaics Research Collaborations due to their high potential impact on LCOE and suitability for crosscutting research that goes across

traditional technology-specific boundaries. Applicants may apply to a research area in this list or develop their own research area. In all cases, applicants should explicitly and quantitatively discuss the likely impacts of their proposed work on the performance, cost, and reliability of PV technologies at the research and/or the commercial scale. They should clearly explain how the proposed team has access to both the necessary capabilities to rapidly evaluate and iterate new designs and the necessary technologies and stakeholders to meaningfully improve upon the industrial state of the art.

Where appropriate, applications to Topic Area 1.1 should synthesize and leverage currently funded solar research efforts into the proposed research program. Additional information regarding the required content and form for Concept Papers and Full Applications can be found in the Application and Submission Information section of this document.

Materials, Interfaces, and High-Efficiency Cell Development

This research area is intended to both expand and synthesize the growing body of knowledge surrounding PV material development, loss analysis, and loss mitigation to enable the continued progress in cell efficiency and the translation of those efficiency gains to cells and modules at the production scale.

Scientific investigations of contact materials and interface properties have begun to reveal trends and commonalities in behaviors among various absorber technologies. Applications to this area should focus on developing interdisciplinary, and potentially multi-absorber, efforts to enhance understanding across the spectrum of PV-relevant materials and processes among team members in the development of improved cell and module architectures and integrated systems solutions. A representative cell-level goal is to improve contact and interface materials and enhance absorber performance for a range of high-efficiency, stable, simple-to-manufacture device structures. Relevant work in this area includes:

- The modeling, fabrication, and characterization of new contact materials, and the translation of existing contact materials from one absorber technology to another
- The development of new deposition methods that substantially enhance the commercial potential of high-performance cell designs that are not currently cost-competitive
- The identification, quantification, and attribution of power loss mechanisms to specific materials, interfaces, or defects with a particular cell technology
- The application of contact and interfacial learnings from one absorber to another, particularly through collaborations among researchers specializing in different absorber technologies

- The integration of new contact architectures into high-efficiency cells, including any necessary modifications to the deposition or processing of the absorber layer

Teams seeking to develop projects within a defined research area should emphasize the participation of cell and module manufacturers, tool vendors, material suppliers, manufacturing quality assurance consultants, system integration engineers, and other relevant firms and specialists, and should clearly define the anticipated impact on cost and performance of the proposed technology improvements.

Advanced Photovoltaic Manufacturing Science and Technology

This research area intends to support industry-guided or industry-led collaborations that work to develop new tools, materials, or processing methods for solar manufacturing that extend beyond the existing road maps of industrial research and development. Successful projects will improve the manufacturing processes, equipment, outcomes, or cost for any industry partners and for the U.S. PV industry as a whole. Industry partners relevant to this research area include PV material suppliers, and manufacturers of equipment, system components, and monitoring and analysis tools that address any problem in the manufacturing chain, especially those related to total yield, from PV materials to cell processing, module packaging, and quality-assurance testing. Relevant work in this area includes:

- Improving equipment or processes for manufacturing PV system components, including the design and modeling of new tools and methods that could potentially reduce manufacturing capital or operating expenditures
- Developing manufacturing equipment, processes, or methods that are capable of producing high-efficiency cells and/or modules, including tandem cells and modules, and balance-of-system components at prices that will be competitive with the larger PV market
- Supporting the detailed analysis of manufacturing tools, facilities, and business models in order to reduce costs and enhance profitability in the U.S. manufacturing of PV materials, modules, and system components
- Developing, prototyping, and validating metrology and analysis tools for PV manufacturing, yield and quality assurance

Applications should clearly describe the problem, the reasons that the existing PV industry cannot address the problem with similar or better efficacy, and the anticipated impact on U.S. PV manufacturing. Applicants should state what parts of the project will be proprietary and what results will be disseminated to the broader public. Projects focused on perovskite manufacturing should work to specifically address the quantitative targets provided in the Perovskite Module Manufacturing and Long-Term Durability research area below.

System Optimization for Increased Energy Yield and Lower Operations and Maintenance Costs

Applications to this area should work to increase the annual energy production and lower the O&M costs of residential-, commercial-, and utility-scale PV systems. Of particular interest are approaches that acquire and analyze large data sets to improve the understanding of PV system performance over time or reduce O&M costs. Projects also should describe how data and results will be shared in order to benefit the PV community. Examples of relevant work in this area include but are not limited to:

- Advances in PV system design, system hardware, or system installation, including racking and trackers. This includes approaches leading to higher ground coverage and inverter utilization, improved module handling during installation, or more effective incorporation of energy storage.
- Methods and platforms for the measurement, analysis, and prediction of system performance and energy yield. This may include big data analysis to better understand performance or optimize O&M schedules.
- Tools and techniques for the improved monitoring, characterization, and troubleshooting of fielded modules and other system components through automated data analysis and reporting. This may include the development of tools and techniques that measure module or string-level performance, troubleshoot low system power output, or connect fielded module degradation or failure with system or module-level bills of materials.
- Advanced system components and hardware that enhance energy yield. These may include new module architectures, bifaciality, shading or soiling mitigation, or the use of module-level power electronics, power optimizers. Proposed methods should also consider the optimum mounting methods and location of the power electronics—such as on frame or backsheet, or splitting the components for maximum benefit—and must include a reliability assessment of the proposed approach.
- Methods and tools to assess, quantify, predict, and improve the long-term reliability of microinverters, direct-current-to-direct-current optimizers, and other electronic circuitry that is integrated into modern PV modules. This includes developing testing methods and protocols to detect failure points and verify reliability before the components are installed or during field operation.

Successful projects will quantify any added or reduced LCOE associated with implementing the proposed technology or approach and should quantify any expected net benefits. Partners could include cell and module manufacturers; system owners and operators; engineering, procurement, and construction firms; O&M providers; or other relevant specialists.

Perovskite Module Manufacturing and Long-Term Durability

This research area supports the development and implementation of highly scalable, integrated manufacturing systems for perovskite modules, as well as reliability testing or demonstration studies through a coordinated effort that leverages existing U.S. research. Projects can focus on either single-junction or tandem perovskite devices and should target a production line performance of:

- Capacity of a single line >= 1 gigawatt per year
- Module efficiency >= 20%
- Module cost <= $\$0.20/W_{DC}$
- Module lifetime >= 20 years (at > 80% relative module performance)

Successful projects should detail the ability and risks to achieving the production targets listed above and justify a credible path to market entry within five years of project completion. Applications should define the anticipated impact on cost, throughput, and performance of any newly proposed technologies. Applications in this area should address multiple or all of the following aspects of perovskite cell and module development through research efforts that are either directly supported by the project or that leverage existing efforts of proposed team members:

- Absorber layer enhancement: new materials, processes, and equipment systems, including new deposition approaches as well as rapid annealing, curing, or other post-treatment processes
- Transparent conductive layers: new materials, processes, or systems
- Carrier-selective contacts and junction formation: new materials, processes, or systems
- Encapsulation and packaging: new materials, processes, or methods
- Material production and supply chain: For any of the items above, projects that seek to improve quality, cost, and quantity of process materials and/or traceability of the supply chain will be considered.

Successful projects will work to convene and coordinate existing U.S.-based efforts on perovskite module development funded by SETO and other funding agencies. Applications should not include significant infrastructure expansions. Instead, applicants are encouraged to identify partner facilities that can be used for scaling demonstrations and/or partners that can leverage existing facilities and capabilities, especially high-throughput manufacturing systems, characterization facilities, and testing facilities.

Low-Cost Substrates for Single-Crystal High-Efficiency Cells

This research area seeks to fund collaborations that reduce the substrate costs to make wafers and high efficiency cells. To lower the LCOE of PV systems, the efficiency of standard commercial cells must increase, either through the use of materials with better optoelectronic properties or by using multiple junctions that

capture more of the solar spectrum. Current record efficiencies of single-junction and multijunction solar cells have been set using III-V materials. However, the cost of such materials and growth processes are cost-prohibitive compared with industry-standard technologies, such as those containing cadmium telluride and silicon PV.

Most high-efficiency single-crystal PV technologies rely on wafers cut from an ingot. For silicon, the wafer is directly converted into the cell. For absorbers based on III-V materials, the wafer generally serves as a template on which the active layers are epitaxially grown. Obtaining and preparing a suitable substrate for epitaxial growth can add significant costs. Substrate and surface conditioning costs represent up to one-third of the total cell manufacturing cost for III-V based cells, as shown below in Figure 7.

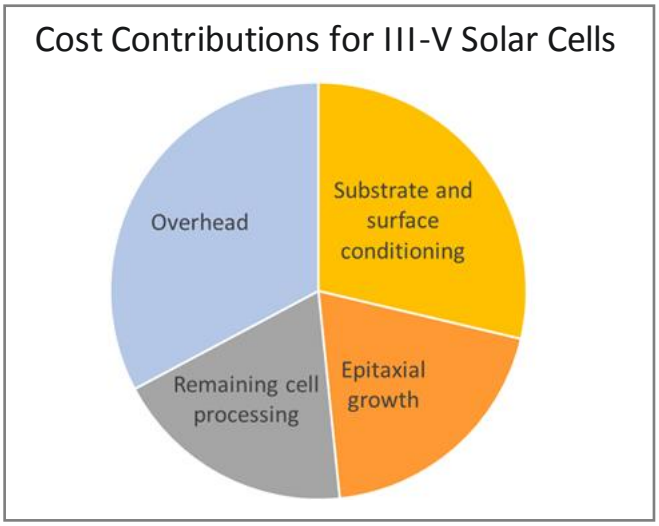

Figure 7. *Cell manufacturing cost breakdown showing substrate, device epitaxial growth, device processing, and overhead costs for a sample single junction III-V solar cell. Data adapted from Horowitz et al. (2018).*[16]

In order to reduce the cost of single-crystal PV, this research area will support applications that address substrate costs to make wafers and cells. Potential partners include materials and device scientists, process engineers, and industrial stakeholders. Relevant work in this area includes:

- The identification and testing of low-cost substrates that can be used to grow single crystalline epitaxial materials which result in cell efficiencies comparable to the state of the art

[16] National Renewable Energy Laboratory. *A Techno-Economic Analysis and Cost Reduction Roadmap for III-V Solar Cells.* https://www.osti.gov/biblio/1484349-techno-economic-analysis-cost-reduction-roadmap-iii-solar-cells, November 27, 2018.

- The development of substrate reuse processes that increase throughput beyond currently available processes and increase the number of reuses to greater than 100 cycles

Applications should quantify the expected project impact on cell cost and performance, with the goal of reducing substrate cost contributions to the cell production cost, which includes substrate material cost, surface reconditioning, and number of reuse cycles, to less than $0.02 per W_{DC}. Applicants are encouraged to adapt learnings and expertise from traditional PV materials and adjacent areas in semiconductor processing, crystal growth, and optoelectronic device fabrication to reach this goal.

PV System Recycling and End-of-Life Management

This research area seeks to fund collaborations to address the growing recycling and end-of-life management issues associated with PV systems. As increasing amounts of PV is installed in the United States, the quantity of PV modules and system hardware requiring disposal due to component failure, routine replacement, or voluntary site decommissioning is set to increase. Few researchers address the disposal of PV modules, and there is insufficient public information on how system components coming offline are being handled by owners or waste-management operations. Previous analyses of PV system component life cycles and the cost of recycling have mostly relied on theoretical processes, and there is a lack of published experimental and historical data. This research area will support bringing stakeholders together to engage in most or all of the following:

- Surveying the quantity of retired or nearly retired system components to understand the scale and composition of the expected waste stream of PV system hardware
- Identifying recycling technologies from similar waste streams, such as building materials, vehicles, or electronics, that could be cost-effectively applied to PV system recycling
- Establishing tools to inform decisions regarding system management near the end of the system's life, such as decommissioning and replacement, and to assess the residual value of system components at decision time
- Developing and piloting a process for the recycling of PV components equivalent to at least a 10-kilowatt system within the general waste-management system

Applications to this area should include partners such as PV system owners, manufacturers, and waste-management and recycling specialists, and should clearly describe how the project team will gain access to any relevant PV waste materials or recycling facilities.

2. Topic Area 1.2: Small Innovative Projects in Solar (SIPS)

This topic area intends to fund targeted, well-defined projects in PV research that can produce significant results within the first year of performance. If successful, the outcomes will open up new avenues for continued study. The types of projects that are appropriate for the SIPS program are high-risk or innovative work where physical proof of concept, modeling, or theoretical studies are needed to provide evidence for funding a future, potentially scaled-up applied-research project. Projects may address PV technologies at the system or component level. SETO is primarily interested in SIPS projects from novel and/or emerging areas of PV research that have the potential to produce dramatic progress toward a solar LCOE of $0.03 per kWh by 2030. Successful applicants will have a strong team and argument for why their approach will be impactful, with the identification of key metrics and appropriate baselines that clearly demonstrate how the proposal will surpass the state of the art, as well as potential partners upon the project's completion.

This topic area will use an abbreviated application process, which is described in Section IV of this document. Applicants are required to submit an LOI, but Concept Papers are not required. **In order to clear an administrative software restriction of EERE Exchange and be eligible to submit a complete SIPS application, applicants must resubmit their LOI in place of a Concept Paper and upload a summary slide by the Concept Paper deadline.** Applicants will be unable to submit a SIPS application for review if they do not complete the steps listed above. SIPS applications must be submitted by the Full Application deadline using the format provided in Section IV.E.

ii. Topic Area 2: Concentrating Solar-Thermal Power Research and Development

The SETO concentrating solar-thermal power (CSP) research and development (R&D) program supports early-stage research to improve the performance, reduce the cost, and improve the lifetime and reliability of CSP materials, components, subsystems, and integrated solutions. To enable a significant, market-driven, deployment of CSP in the United States, SETO works to achieve the 2030 SunShot targets of $0.05 per kWh for a baseload CSP plant with at least 12 hours of thermal energy storage (TES) and $0.10 per kWh for a peaker CSP plant with a maximum of six hours of TES.

The value proposition of CSP is its ability to enable solar electricity on demand through low-cost integration of TES. Further, CSP systems use traditional turbine-based heat engines, which are used to generate the majority of global electricity. This combination of readily scalable energy storage and proven turbine technology has the ability to provide reliable and flexible renewable electricity production.

State-of-the-art CSP power plants are based on a central "power tower" that uses molten nitrate salts as both the primary heat-transfer fluid (HTF) and the TES material, at a temperature of approximately 565° Celsius. Recent SETO R&D objectives under the Generation 3 (Gen3) CSP[17] funding program have focused on developing thermal transport systems capable of operating temperatures greater than 700°C and integrating them with advanced, high-efficiency power cycles. In addition to lowering solar field costs, integration with high-efficiency, low-cost power cycles is a key element of lowering the cost of energy generation from CSP. SETO is developing these concepts through the Gen3 CSP Systems Integration FOA and Gen3 Lab Support.[18] Additionally, the recent SETO FY 2018 FOA sought CSP projects that spanned a broad domain, touching every subsystem in the plant.[19]

[17] National Renewable Energy Laboratory. *Concentrating Solar Power Gen3 Demonstration Roadmap.* https://www.nrel.gov/docs/fy17osti/67464.pdf. January 2017.
[18] U.S. Department of Energy Solar Energy Technologies Office. https://energy.gov/eere/sunshot/funding-opportunity-announcement-generation-3-concentrating-solar-power-systems-gen3csp.
[19] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-energy-technologies-office-fiscal-year-2018-funding-program-seto-fy2018.

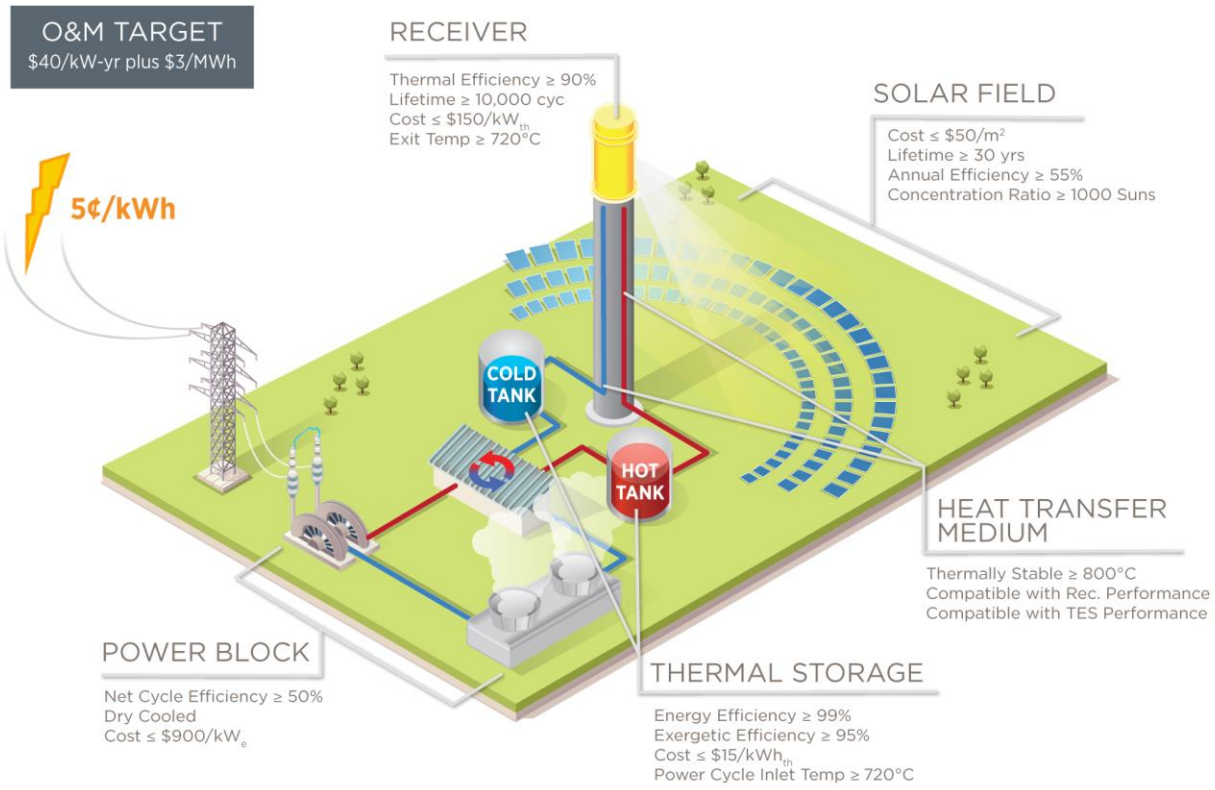

Figure 8. *One combination of subsystem metrics compatible with the SunShot 2030 target*

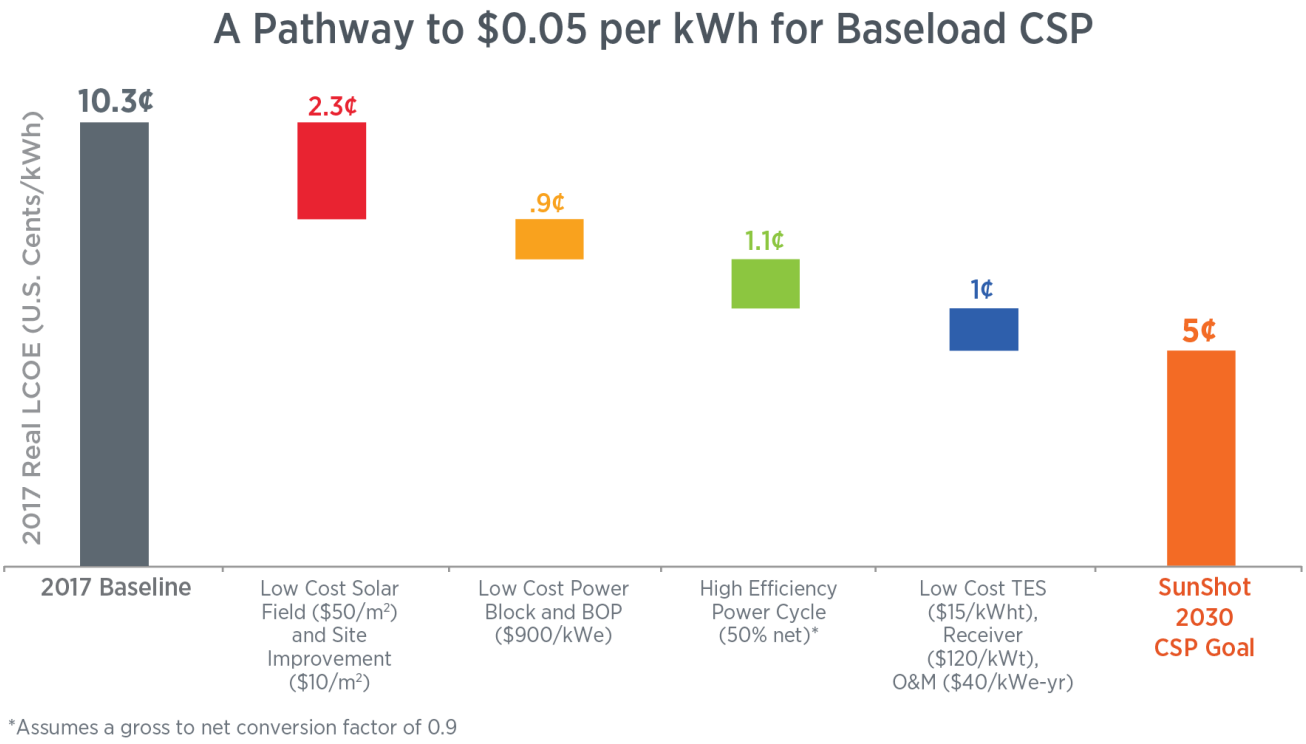

Figure 9. *Waterfall chart showing one possible path to achieving an unsubsidized levelized cost of electricity of $0.05/kWh for a concentrating solar power tower plant in the southwestern United States (BOP = Balance of Plant)*

The challenges in achieving the SunShot 2030 targets for CSP require interdisciplinary solutions throughout a variety of fields in science and technology. There is no single CSP challenge (as shown above in Figure 8[20]) but rather a series of challenges of heat transfer, fluid mechanics, thermodynamics, optical physics, materials science, extreme automation in the solar field, corrosion mitigation, advanced manufacturing, thermo-mechanical engineering design, low-cost sensors and control, and predictive operations and maintenance, among others. In order to clarify the targets, SETO has created a set of point solutions for each subsystem's efficiency, cost, and lifetime. These are presented in Figure 8, with the economic impact by area displayed in Figure 9, above. These goals exemplify only one of many possible combinations of techno-economic metrics that could be employed to build a $0.05 per kilowatt-hour of electricity (kWh_e) CSP plant.

[20] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/sunshot-2030.

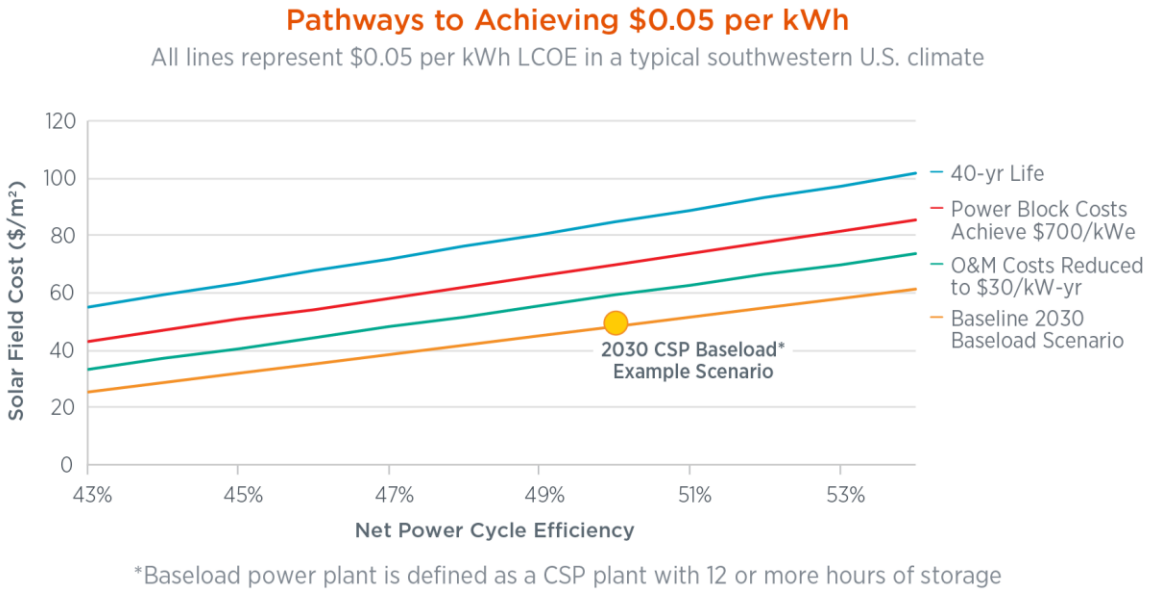

Figure 10. *The "Baseline 2030 Baseload Scenario" in this graph indicates a combination of solar field cost and net power cycle efficiency—the two most influential technical measures—that meet the 2030 SunShot baseload target of $0.05 per kWh, using the metrics in Figure 8. The other lines show that reducing annual O&M costs, lowering power block costs, and validating longer plant lifetimes may relax the required targets for solar field cost and power cycle efficiency. Each line represents a single change from the baseline scenario. Achievements significantly exceeding the baseline targets are highly impactful.* [21]

It is important to recognize the broad solution space of cost and performance objectives that are compatible with the SunShot targets. Likely solutions will vary as innovations occur in the many technical fields touching CSP. In the topics below, specific subsystem targets are often described to focus objectives and simplify discussion. However, Figure 10, above, shows how successful improvements to certain aspects of a CSP plant could relax the requirements on other areas. While these trade-offs can and should be used to better describe the value of a proposed innovation, applicants should not invoke undefined improvements in areas outside their proposed R&D as justification for relaxing technical metrics. Alternately, Figure 10 demonstrates how innovations going beyond the SunShot metrics have an increased value proposition. With this in mind, concepts that can achieve cost reductions, efficiency increases, or other relevant metrics significantly beyond those outlined in Figure 8 have additional value to SETO.

Areas of Interest for Applications to Topic Area 2

The CSP program intends to fund research in the following specific topic areas:

[21] National Renewable Energy Laboratory. *The Potential Role of Concentrating Solar Power within the Context of DOE's 2030 Solar Cost Targets.* https://www.nrel.gov/docs/fy19osti/71912.pdf. January 2019.

- **Topic Area 2.1: Firm Thermal Energy Storage** - Concepts that expand the dispatchability and availability of CSP plants to provide value to grid operators
- **Topic Area 2.2: Materials and Manufacturing** - Solutions that will significantly reduce the cost of manufacturing CSP components to achieve the office's 2030 cost targets
- **Topic Area 2.3: Autonomous CSP Collector Field** - Solutions that enable a solar field that can fully operate without any human input, reducing costs and maximizing thermal energy collection efficiency

The DOE National Laboratories provide unique capabilities, such as the National Solar Thermal Test Facility,[22] a test bed for novel CSP technologies, and support of the System Advisor Model,[23] a tool for estimating the performance of power plant designs. As appropriate and needed, applicants may design projects that take advantage of unique DOE facilities and capabilities. In such cases, justified projects and clear budgets must be developed in consultation with the relevant national laboratory, and the applications must include a letter of commitment from the associated national laboratory, confirming the proposed budget, scope, and availability of the facilities and/or laboratory personnel to complete the proposed work within the proposed project schedule. Note that collaboration with, or the use of facilities at, a DOE national laboratory is not a requirement for application to this FOA. Applications will be evaluated on their own merit as per the criteria set forth in this FOA.

Applicants to Topic Area 2 may propose projects that are R&D only or that include demonstration activities, and may propose project budgets up to $8 million in federal funding in Topic Areas 2.1 and 2.3, and up to $5 million in federal funding in Topic Area 2.2. However, applications for the highest funding levels will have to justify that their proposed concepts are ready to be scaled up and that their projects will retire significant technology risk, follow aggressive schedules, and culminate in a meaningful technology demonstration. See Section III.B. for cost share requirements for projects that propose R&D and/or demonstration activities.

Principal investigators and their team are expected to produce high-impact outcomes with a view toward commercialization and wide dissemination, including pursuit of patents, licensing, or other intellectual property protection, and publication of the results of their funded research in high-visibility, high-impact, peer-reviewed journals.

[22] Sandia National Laboratories. http://energy.sandia.gov/?page_id=1267.
[23] National Renewable Energy Laboratory. https://sam.nrel.gov/.

1. Topic Area 2.1: Firm Thermal Energy Storage

This topic solicits applications that can expand the value of the electricity generated from a CSP plant beyond metrics associated with energy production. TES decouples solar energy collection from power generation, which means that the value of a solar plant may derive from either the power generated, the ability to generate power during high demand periods due to storage, or both. This expands the market opportunities in which CSP can compete. In other words, firm TES concepts may derive their impact due to increased plant availability rather than increased energy production. Such innovative concepts have meaningful value only if their capital costs are sufficiently low.

Projects are sought in three areas:

- Long-term TES: Systems storing energy for weekly or seasonal dispatch
- Pumped heat electricity storage for CSP: Concepts to enable charging of TES via off-peak grid electricity
- Commercializing TES: Projects pursuing near-term market adoption

TES in CSP plants can take a variety of forms. The TES concepts that are of interest in this topic include systems that use the **sensible** heat stored by changing the temperature of a medium, the **latent** energy stored and released during the phase change of a material, or the **thermochemical** energy stored in a cycled endothermic/exothermic chemical reaction.[24]

Commercial CSP plants with TES currently use sensible storage in solar salt.[25] In molten salt power tower configurations, the solar salt operates in a 270°C to 565°C range, in a **direct** configuration, where the heat transfer fluid/medium (HTF) used in the receiver also serves as the thermal storage medium.[26]

Alternatively, the TES system can be **indirect** in which the medium storing energy requires a thermal exchange with the HTF. For example, in some commercial CSP trough plants, a thermal oil is used as the HTF and solar salt is used as the TES medium.[27]

[24] *Journal of Thermal Science and Engineering Applications*. "Technical Challenges and Opportunities for Concentrating Solar Power with Thermal Energy Storage." http://thermalscienceapplication.asmedigitalcollection.asme.org/article.aspx?articleid=1690813 May 17, 2013.
[25] Solar salts contain 60% sodium nitrate and 40% potassium nitrate.
[26] An example is Crescent Dunes Solar Energy Project in Nye County, Nevada.
[27] An example is Solana Generating Station in Gila Bend, Arizona.

Additionally, **hybrid** system concepts could exist that use a combination of direct and indirect storage and multiple TES media.

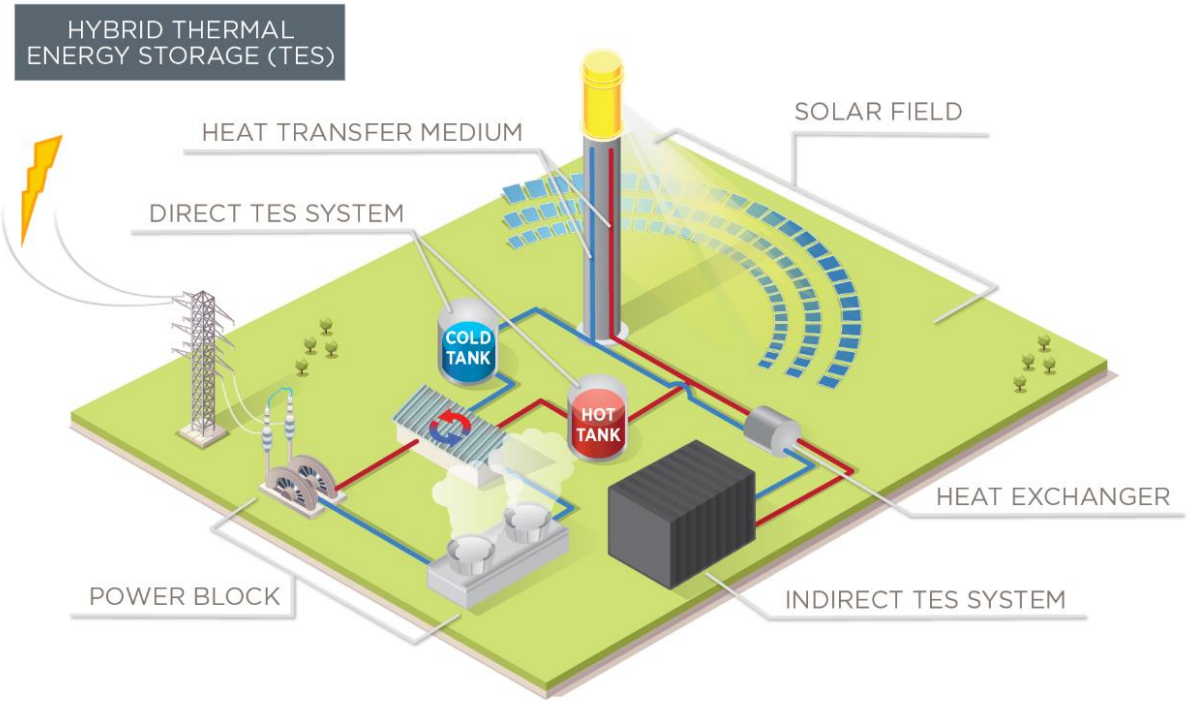

Figure 11. *CSP plant with hybrid TES: Two different TES systems may be used because each has a unique value and cost. In one possible embodiment, shown here, the direct TES system provides a more efficient and timely response, while the indirect TES system can store substantially more energy at a cheaper cost per kWh.*

Applicants should describe the total cost of their proposed TES system in dollars per kilowatt-hour thermal ($/kWh$_{th}$) for a specified system concept, including the specified size. To fully consider efficiency and cost, the project must account for the following components when describing a complete TES concept:

- The TES medium
- The TES containment vessel
- Any relevant heat exchanger, excluding heat exchange into the power cycle working fluid[28]
- Any associated chemical reactor or reactant storage for thermochemical energy storage

Some of these costs scale with the thermal throughput rate ($/kW$_{th}$), while others scale with the amount of thermal energy stored ($/kWh$_{th}$). Note that depending on

[28] If this heat exchanger is intimately integrated with the proposed concept, DOE nominally targets $150/kW$_{th}$ for high-temperature applications at 700°C and $100/kW$_{th}$ for moderately high-temperature applications at 550°C. This budget can be incorporated into a proposed integrated concept.

the plant requirements, the charging rate (kW_{th}) may be very different from the discharge rate (kW_{th}).

Successful projects will consider how the subsystem functions under various operating paradigms of the plant. The conceptual CSP station should be able to discharge energy while collecting sunlight, discharge energy when no or limited sunlight is available, and charge the storage without discharging energy.

Applications to this topic should provide a detailed and quantified energy balance and mass balance to demonstrate a full accounting of energy efficiency and operating modes of the station. A well-designed CSP TES system has high energetic efficiency, η_{TES}, and high exergetic efficiency, ζ, defined as

$$\eta_{TES} = \frac{Q_{out}}{Q_{in}}$$

$$\zeta = \frac{Q_{out}}{Q_{in}} \times \frac{W_{out}}{W_{in}} \approx \frac{Q_{out}\left(1 - \frac{T_\infty}{T_{PB}}\right)}{Q_{in}\left(1 - \frac{T_\infty}{T_{RO}}\right)}$$

where Q_{in} is the total energy transferred from the HTF to the storage system during charging, Q_{out} is the total energy transferred from the storage system to the HTF or power cycle working fluid during discharging, T_{PB} is the temperature of the working fluid at the inlet of the turbine in Kelvin, T_{RO} is the temperature of the HTF at the outlet of the receiver in Kelvin, and T_∞ is the ambient temperature nominally taken to be 298K.

All applications to this topic should consider five characteristics that may be used to compare different approaches for achieving a specified levelized cost:

1. Capital expenditures
2. Operational expenditures
3. System lifetime, which may dictate maintenance or part replacements covered in the operational expenditures
4. Energetic and exergetic system efficiency
5. The cost of energy input: In topics A and C, below, this is represented by the cost of an additional solar collector field to make up for exergetic inefficiency. In topic B, this is simply the cost of charging electricity.

TES applications of interest must be responsive to one of the following categories:

A. Long-Term Thermal Energy Storage

Applications responsive to this topic will enable CSP plants with TES to supply weekly or seasonal storage capacity. Today's commercial CSP plants with TES are designed

to discharge TES soon after its solar-driven charge, typically within 24 hours. This allows the plant to provide electricity at a specific hour of high demand, to stop generating during low demand hours, and to provide electricity in periods where other energy resources are unavailable.

However, if little or no sunlight is available within 24-48 hours, the CSP plant is designed to operate at partial or no capacity. This solar deficit limits TES charge and constrains the flexibility and availability of a CSP plant, ultimately capping its capacity value to grid operators. Even in areas of the country that have a lot of direct sunlight, it is difficult to achieve the high annual availability sought in capacity credit markets, often above 95% for the specified operation window, without significant, and costly, overbuild of the solar field.

Successful projects will design a CSP plant to operate over several days without sunlight, which would require weekly TES, or extended periods of limited sunlight, such as winter months, requiring seasonal TES. To provide firm capacity in periods of reduced and highly variable sunlight, weekly TES should be able to maintain plant availability at peak demand periods for up to seven days. Alternatively, the systematic decrease in peak solar energy and clear-sky days during winter creates a potential opportunity for seasonal TES. A plant taking full advantage of seasonal TES should be able to supplement the limited sunlight over the winter with energy collected and stored during other months. In both cases, the concept should consider how reserve capacity is built up over time with minimal additional total plant cost.

The value of weekly or seasonal TES is strongly linked to the plant's energy market and operating regime. To describe a commercially relevant system, applicants should, ideally, identify a market where weekly or seasonal TES has significant value beyond commercially available daily CSP with TES. These projects should describe the ability of the proposed concept to respond to that market need, including a quantification of extra costs that come with making the solar field bigger.

As an alternative to performing market analysis as part of their applications, applicants can assume a requirement of an eight-hour discharge from 4 p.m. to midnight every day. In this case, the availability of the plant is the number of hours the system can generate electricity, divided by the annual required number of hours, so, 365 days multiplied by eight hours. The National Solar Radiation Database[29] can provide solar irradiation data that applicants can use as an input to their modeled proposed availability.

[29] National Renewable Energy Laboratory. https://nsrdb.nrel.gov/.

- For applications for weekly storage, proposed solutions must be able to generate electricity eight hours a day for at least seven consecutive days with a 75% reduction in average direct normal sunlight.
- For seasonal storage, proposed solutions must be able to supplement the solar energy collected during the winter with thermal storage collected during the rest of the year. Given a selected U.S. site's solar irradiation, applicants should describe the percentage of hours over the two months with the lowest amount of direct normal irradiance, or solar energy received per unit area, at which they can achieve full electricity generation at the plant's design point. At least 50% of energy dispatched during the two months with the lowest amount of direct normal irradiance must come from thermal energy stored from prior months.

Successful concepts will prove weekly or seasonal TES plant designs at a competitive commercial cost. Applicants must describe the following features and purposes of any proposed technology:

- The projected cost of the TES system in $\$/kWh_{th}$. Other quantitative metrics can be used to supplement the explanation of the TES cost and the proposed value.
- An analysis of system losses via both the first law of thermodynamics and the second law of thermodynamics. Application of the first law should account for energetic losses in charge, discharge, and daily system loss rate. For thermochemical energy storage concepts, sensible losses should be closely accounted for. Second-law losses should clearly define assumptions about the power cycle as well as solar charging temperature.
- An explanation of the likelihood that the proposed system will operate for the target lifetime, assumed to be 30 years. This should include a detailed explanation of the mechanical and chemical integrity of the system.
- Concepts should be compared to a commercial solar salt technology baseline used to respond to the same identified market need.[30]

Applications Specifically Not of Interest

- Concepts in which added availability is primarily the result of increasing the size of the solar collector field relative to the generator's power capacity, or solar multiple
- Concepts in which existing commercial TES could provide the same benefit

B. Pumped Heat Electricity Storage for CSP

This topic intends to advance pumped heat electricity storage (PHES) devices. These devices can provide low-cost storage by using an electrically powered thermal heat

[30] Abengoa Solar, Inc. *Advanced Thermal Storage for Central Receivers with Supercritical Coolants.* https://www.osti.gov/biblio/981926. June 15, 2010.

pump to generate heat that can be stored until dispatched to the grid through a turbine. PHES can be a stand-alone electricity storage technology or a hybrid with CSP to enable charging of TES by either the grid or the sun, depending on energy availability. This additional charging mechanism allows a CSP-plus-PHES plant to function more like a PV-plus-battery plant, expanding its value to grid operators by providing more reliable and flexible thermal storage capacity. Several PHES concepts have been described in literature with varying value for hybridization with CSP.[31,32,33,34]

Each application should quantify the change in levelized cost of energy (ΔLCOE) relative to a traditional CSP plant without a heat pump. The five quantities that should be considered are capital expenditures, operational expenditures, lifetime, efficiency, and cost of energy input. For PHES applications, efficiency should be defined by the round-trip efficiency of electricity from the grid back to the grid. The cost of energy is the cost of electricity bought from the grid. For the sake of simplicity, applicants should assume a $0.025 per kWh cost of charging electricity and a 30-year lifetime. However, ΔLCOE does not capture the increased value to the grid gained by improving plant availability. Rather, it is most useful for comparing technologies competing for a similar market availability. Concepts will be compared primarily on their day-one cost, the round-trip efficiency, likelihood of achieving the lifetime target with any anticipated operations and maintenance, and how those values affect ΔLCOE. Of these inputs into ΔLCOE, capital expenditure is the most critical for concept viability.

[31] *Journal of Renewable and Sustainable Energy*. "Pumped Thermal Grid Storage with Heat Exchange." https://www.researchgate.net/publication/318870559_Pumped_thermal_grid_storage_with_heat_exchange. July 2017.

[32] Aga, V. et al. "Supercritical CO2-Based Heat Pump Cycle for Electrical Energy Storage for Utility Scale Dispatchable Renewable Energy Power Plants." https://businessdocbox.com/Green_Solutions/69467942-Supercritical-co2-based-heat-pump-cycle-for-electrical-energy-storage-for-utility-scale-dispatchable-renewable-energy-power-plants-abstract.html. March 2016.

[33] *Energy Conversion and Management.* "Levelised Cost of Storage for Pumped Heat Energy Storage in Comparison with Other Energy Storage Technologies." https://www.sciencedirect.com/science/article/pii/S0196890417308713. September 2017

[34] *Applied Energy.* "Integration of Heat Pumps into Thermal Plants for Creation of Large-Scale Electricity Storage Capacities." https://www.sciencedirect.com/science/article/pii/S0306261916314908. December 2016.

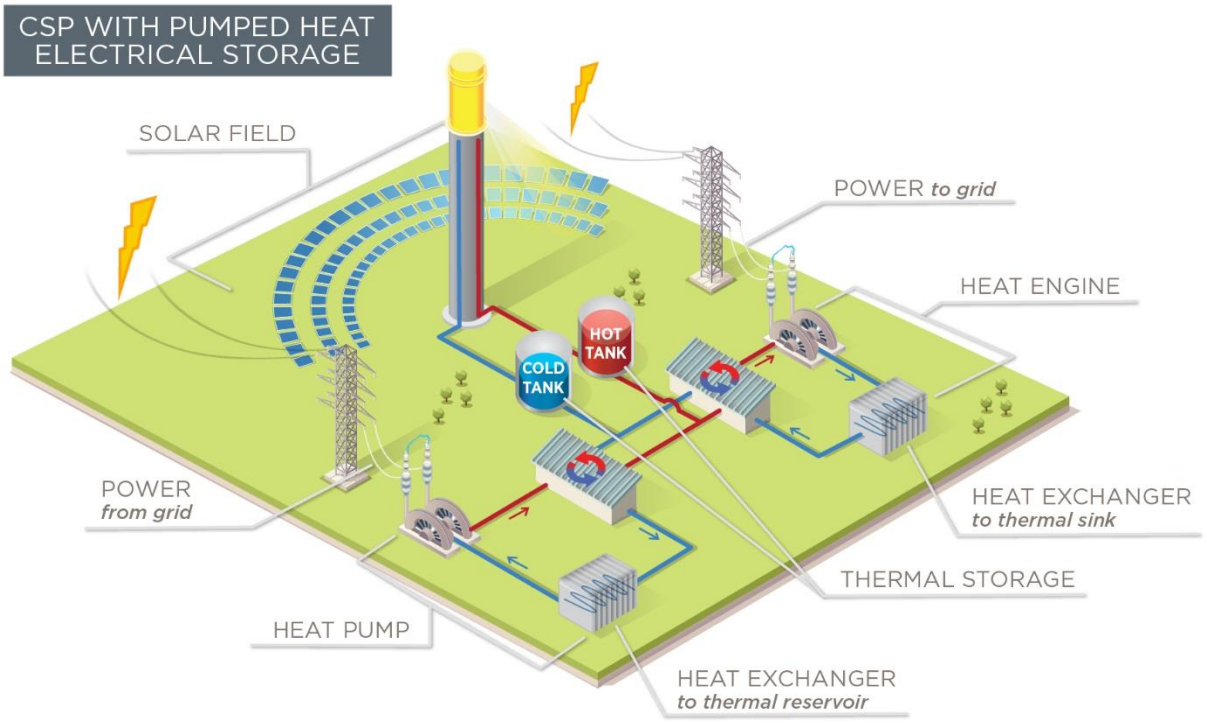

Figure 12. *Layout of a CSP plant with a pumped heat electrical storage system*

C. Commercializing TES

This topic intends to develop innovative TES designs with a clear pathway to reducing costs and have the potential for rapid commercialization. Over the past decade, SETO has invested in R&D for a variety of novel sensible, latent, and thermochemical TES systems.[35] However, technical barriers remain before these projects achieve commercial relevance.

In order to ensure commercial relevance, applicants should either be a for-profit entity or have an industrial partner with a specified cost-share contribution. Projects should be well positioned to attract investment and transition their new technology into the private sector following the completion of their award.

Successful projects will demonstrate both technical and commercial impact, and will work to achieve the following temperature and cost targets:

1. $15/kWh$_{th}$ for more than 650°C. Concepts in this temperature range are appropriate for Gen3 CSP systems.
2. $10/kWh$_{th}$ for 500°C-649°C. This temperature range corresponds, approximately, to current commercial CSP systems.

[35] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/concentrating-solar-power-competitive-awards.

3. $5/kWh$_{th}$ for 100°C-500°C. This "low temperature" range corresponds to many potential solar industrial-process heat applications.

Applications should address the following areas:

- Technology development: Applications should define technology performance goals, cost goals, and development schedules while providing a detailed description of development risks and mitigation plans.
- Cost and value evaluation: Applications should present a basic cost model that estimates the commercial opportunity for the proposed technology. This should describe a plan to develop and validate a sophisticated cost model, including plans to quantify and reduce data and methodology uncertainties and incorporate third-party feedback into the development process.

In addition, applicants should provide a plan for stakeholder engagement and business development. Within it, applicants should provide all of the following:

- A detailed plan for enterprise growth and target sectors, and a schedule for stakeholder engagement, including a plan to incorporate feedback
- A commercialization plan, which should include key demonstration and investor activities
- A strategy for feedback on R&D goals from customers to guide development requirements in the anticipated market

At least 25% of the project scope should be directed toward efforts to commercialize the product. Commercialization activities of interest include but are not limited to:

- Completion of commercially relevant prototype systems
- Demonstration of prototype performance to stakeholder groups
- Review of a cost model by commercial partner(s) and feedback into technical design
- Letters of commitment agreeing to advance the technology further if the award is successful, which may include a large-scale demonstration, additional commercialization activities, or integration into a specific commercialization opportunity
- Cost share from commercialization partners
- Business model development, review, and evaluation

Applications Specifically Not of Interest

- Projects primarily addressing building space-heating uses
- Projects primarily addressing water heating below 100°C

2. Topic Area 2.2: Materials and Manufacturing

This topic intends to fund projects that will significantly reduce the cost of manufacturing CSP components toward SETO's 2030 cost targets. To achieve the

2030 target for CSP plants with greater than 12 hours of TES, the industry must reduce costs by half.[36] To allow the industry to attain 50% reduction in capital cost, it is essential to improve the performance of materials and reduce the manufacturing cost of the components that comprise the CSP plant.

In addition to the challenges of lowering capital expenditures, new CSP plants must also contend with the uncertainty of performance, as well as construction and commission delays due to limited experience or unexpected construction complexity. These concerns will likely be exacerbated by high-temperature Gen3 CSP concepts, which may push the limits of material capabilities to temperatures between 700°C and 800°C. Table 1, below, shows a high-level estimate of system costs and LCOE contributions that lead to current LCOE status and future targets.[37]

Cost category (LCOE Contribution)	Cost Metric	2018 ($0.103/kWh)	2030 ($0.05/kWh)
Site improvement	$/m^2	16 (0.26)	10
Heliostat total	$/m^2 reflective area	145 (2.32)	50
Receiver (including tower and piping)	$/kW$_{th}$	180 (1.53)	120
TES	$/kWh$_{th}$	24 (0.78)	15
Power cycle	$/kW$_e$	1,440 (1.95)	900
Total direct cost	$/kW$_e$	6,300	2,975

Table 1. *Broad cost reduction goals targeting $0.05 per kWh. While indirect and O&M costs are important contributors to LCOE, this table reflects only capital cost targets, which are the main focus of materials and manufacturing innovations.*

This topic focuses on potential manufacturing and materials innovations that are relevant to:

- The solar collector field and associated components: mirrors, supports, drives, and control systems
- Receiver and associated components: piping, pumps, tower structure, insulation, heat tracing, headers, and valves
- Heat-transfer media and associated components: piping, pumps, and corrosion mitigation
- Thermal energy storage and associated components: insulation, structural support, pumps, and ullage systems
- Power blocks, including the primary heat exchanger and dry cooling systems

[36] The present-day direct capital cost for a nominal 100 MWe baseload plant with a solar multiple of 2.7 and storage capacity of 14 hours exceeds 6,300 $/kWe. To attain the LCOE goals, total direct capital cost should be reduced to 2,900 $/kWe.

[37] National Renewable Energy Laboratory. *The Potential Role of Concentrating Solar Power within the Context of DOE's 2030 Solar Cost Targets.* https://www.nrel.gov/docs/fy19osti/71912.pdf. January 2019.

Two complementary approaches may be taken to achieve lower costs, both of which are of interest in this topic:

A. The development of materials that have not been previously applied to CSP. Materials of interest should have identified manufacturing pathways that could potentially be expanded to commercial scale at competitive costs.
B. The development of novel manufacturing techniques that could dramatically lower the cost of known materials that are already being used for CSP or other similar applications.

Within this topic area, SETO encourages applications that explore and discover new materials as inputs to the manufacturing processes. Projects that include materials targeted for use in high-temperature applications like Gen 3 CSP, which have operating temperatures between 700°C and 800°C, should also make a compelling argument about how those materials are capable of withstanding oxidation in air and the likelihood of predictably acceptable mechanical properties.

While advanced manufacturing processes include a large pool of potential technologies, the solar office is particularly interested in additive manufacturing for CSP applications. Additive manufacturing offers several advantages, including reduced material waste, lower energy intensity, reduced time to market, just-in-time production, small but economic production runs, and building components not possible with traditional manufacturing processes. This may be particularly important for CSP applications, where the size of the industry is not large enough to warrant production lines dedicated to CSP-relevant products.

This topic also seeks applications that use advanced manufacturing techniques, not limited to additive manufacturing, and CSP-relevant materials to produce components relevant to CSP in form factors that can be used by CSP plant designers. Components that may need to be redesigned for next-generation CSP systems include but are not limited to electrochemical sensors, valves, flanges, bends, elbows, blinds, and expansion joints, primary salt-to-supercritical carbon dioxide (sCO_2) heat exchangers, headers, solar receivers, pipes and pipes with internal linings of at least a half inch internal diameter, thermal insulation, chemical barrier coating, and components of sCO_2 power cycles.

An example of a key component requiring manufacturing-based innovation is nickel-based superalloys, which are the only commercially available materials appropriate for receivers and piping systems at high temperatures. While some cost reduction is expected along with increased demand and experience, the likelihood that these materials will meet the substantial reductions necessary to hit 2030 targets is uncertain. In addition, the challenge of shaping these high-stiffness materials into the pipe bends required to mitigate thermal stress may result in cost-prohibitive

piping designs. Projects that work toward cost-competitive piping and receiver tubing through changes in pipe design and fabrication processes are highly relevant.

Alternate approaches to power tower design that can attain LCOE targets are encouraged, as are manufacturing and materials development for such approaches. Table 2, below, maps components and subcomponents to possible materials advancement and manufacturing concepts for present-day power tower design. The material and manufacturing ideas in Table 2 should be viewed as suggestions, not recommendations, and proposals for additional solutions are welcome.

Successful applications will consider materials-level analysis of manufactured test specimens under CSP-relevant operating conditions prior to continuing to a "full part" or component build. These analyses should include electrochemical and mechanical tests, as appropriate. Mechanical testing should proceed according to internationally recognized standards, such as prescribed by the National Institute of Standards and Technology and the American Society of Mechanical Engineers.[38, 39]

Applications to this topic should advance the state of the art through the development of readily assembled functional components. Applications should address the following risks involved in the development of new materials and manufacturing processes:

- Integration and validation at an early stage of the qualification and certification considerations of the materials
- Joint development with material suppliers and end-users as a requirement for rapid uptake by industry
- Modeling, standardization, and regulatory aspects, including process and materials qualification, and especially considering American Society of Mechanical Engineers code cases
- Quantification of improved functionality, properties, quality, and lifespan of fabricated pieces
- Evaluation of matching materials properties to the production process—for example, to enable the joining or bonding of dissimilar materials.

[38] U.S. Department of Commerce National Institute of Standards and Technology. "Mechanical Properties Testing for Metal Parts Made via Additive Manufacturing: A Review of the State of the Art of Mechanical Property Testing." https://www.nist.gov/publications/mechanical-properties-testing-metal-parts-made-additive-manufacturing-review-state-art. 2012.

[39] Some additional standards of particular relevance to CSP include **tension tests** (ASTM E21, ASTM E292); **modulus tests** (ASTM E111, preferred E1876, further preferred, with consideration of high through-put testing) ASTM E1875); **fatigue tests mimicking diurnal cycles** (ASTM E647, ASTM E2760); and **crack growth** (ASTM E 1457, ASTM E1681).

Cost and Performance Targets For CSP Components and Potential Material And Manufacturing Innovations				
Component/ System	**Subcomponent**	**Nominal Cost and Performance Targets**	**Materials (Examples)**	**Manufacturing (Examples)**
Collector Field	Heliostat Frame Structural Support	Design and cost are oriented to reduce the cost of the solar field below $50/m^2	Alternates to steel including composites and wood	Assembly for alternate materials
	Drives		Material alternatives to drive systems	
	Foundation		Materials for lower cost foundation	Reduction in labor cost of entire collector assembly using advanced manufacturing
Receiver/ Tower	Tower	Cost is less than or equal to $50/kWth (assumed to be 40% of estimated receiver cost); tower construction schedule is less than one year		Rapid assembly, such as a bolted spaceframe design
	Receiver Assembly	HTF outlet temperature higher than 725 °C-775 °C; maximum wall temperature of about 800 °C; fatigue-limited life greater than 10,000 cycles; receiver cost less than $75/kWth	Cheaper materials for high temperature receivers; materials for cavity receivers; materials for salt-facing components that are temperature-, creep-, and corrosion-resistant	Manufacturing and assembly for lower cost; high-temperature receivers
Heat Transport System	Pump(s)	Creep- and fatigue-limited materials	Materials for erosion and temperature resistance	
	Lifts/Particle Elevators	Materials for erosion and temperature resistance; materials for 750°C operation	Lower-cost alternative to high temperature alloys that are temperature-, creep-, and fatigue-resistant	Manufacturing alternatives to mill run production for low volumes

	Piping/Ducts	Maximum operating temperature is about 750°C; corrosion rate in sCO_2 and molten salt is less than 30 µm/y; lifetime is at least 30 years	Ferritic materials and internal coatings/layers that can withstand higher temperature	Unconventional pipe manufacturing processes that can additively inlay a high corrosion-resistant layer
Thermal Energy Storage	Tank wall material Additional salt-facing inner layer material	Material (with or without internal cladding); operating temperature is less than or equal to 750°C; withstand stress corrosion and stress relaxation cracking	Lower-cost corrosion-resistant cladding and insulation material	Lower-cost manufacturing methods and install cladding
	Internal Insulation	Corrosion < 30 µm/y		
	Phase-change system materials and heat exchangers	New innovations in phase-change materials, and heat exchangers that work with phase-change materials	Innovations in materials that will permit additive manufacturing, together with requisite corrosion resistance	Additive manufacturing or alternates to etching for diffusion bonding process
Power Cycle	HTF-sCO_2 heat exchanger	Material hot side temperature is less than or equal to 750°C; material cold side temperature is less than or equal to 750°C; creep lifetime greater than 30 years at 250 Bars, 750°C; corrosion less is than 30 µm/y in molten salt, sCO_2, and particles	Innovations in materials that will permit additive manufacturing, together with requisite corrosion resistance	Additive manufacturing or alternates to etching for diffusion bonding process
	Compressor	At least 85% efficiency at 31°C–41°C compressor inlet; cost target of less than 75 $/kWe	Improvements in bearings and seal materials that will reduce component count, and material improvements in turbine casing, shaft, with integration of cooling as required	Additive manufacturing of bearings and seal assemblies; additive manufacturing of casing and shaft integrated with thermal barrier coating materials and cooling designs (for compressors)

	Turbine	At least 91% efficiency at 715°C turbine inlet; cost target of less than 75 $/kWe		
	Pre-Cooler	Air-cooled heat exchanger; capital cost reduction of less than 100 $/kWe; cooling-fan power consumption reduction less than 5% auxiliary load		Novel hybrid designs and manufacturing methods
	Recuperators	Similar to primary heat exchanger	Similar to primary heat exchanger but corrosion limits on sCO_2 only	

Table 2. *Cost and performance targets for CSP components with potential relevant material and manufacturing innovations*

3. Topic Area 2.3: Autonomous CSP Collector Field

This topic solicits autonomous CSP collector fields that will reduce costs and improve performance for both current power tower technologies and high-temperature Gen3 CSP systems. The concentrating solar collector field, which directs solar flux to an absorber, or receiver, where it is converted to heat, is one of the largest components of the construction cost of a CSP plant, accounting for approximately 25% to 40% of the direct capital costs.

The solar collector field must efficiently concentrate light while minimizing fabrication, installation, and operating costs. Collectors that are able to cost-effectively achieve high concentration ratios can directly improve the efficiency of the receiver. This effect becomes particularly impactful at high receiver temperatures. While CSP technology developers and operators, particularly of power towers, are progressively addressing fundamental issues such as flux spillage, heliostat canting and tracking/pointing errors, mirror cleaning protocols, and communication and controls, more research is required to fully streamline and automate these solutions. Limitations due to human error or speed of alignment and correction result in an inefficient flux profile on the receiver and a reduction in the net receiver thermal energy collection efficiency.

The CSP collector instantaneous optical efficiency, η, as a function of location *(x,y)* and time, *t*, can be defined as:[40]

$$\eta(x,y,t) = \rho.cos\omega(x,y,t).f_{at}(x,y).f_{int}(x,y,t).f_{s\&b}(x,y,t,neighbor\ heliostats) \quad (1)$$

[40] *Renewable Energy*. "Preliminary Design of Surrounding Heliostat Fields." https://www.sciencedirect.com/science/article/pii/S0960148108003376. May 2009.

where ρ is the heliostat reflectivity, which is the combination of mirror reflectivity and soiling, $\cos\omega$ is the cosine effect, f_{at} is the atmospheric attenuation factor, f_{int} is the intercept factor, or spillage efficiency, and $f_{s\&b}$ is the blocking and shading efficiency. Projects in this topic area should seek to maximize the total optical efficiency, η, by considering atmospheric attenuation, blocking and shading, mirror soiling, tracking and canting errors, and concentration ratio in their solution. During typical operation of a CSP plant, as much as 45% of the energy can be lost before light even hits the receiver, as shown below in Figure 13, with blocking or shading and cosine effects combining for about 25% of the loss. Of the other 20%, approximately 2% is usually attributed to attenuation, 1% is attributed to flux spillage, 4% to 5% is attributed to soiling, 6% is attributed to reflectance, and the other losses are attributed to heliostat availability, calibration, forced outages, scheduled outages, and wind downtime, as in the default molten salt power tower model in the System Advisor Model. Note that these numbers will vary depending on the plant design.

In some plants, operations are far from nominal, with losses attributable to factors like the amount of solar flux that misses the receiver, or spillage loss, being much larger than planned (that is, much larger than 1%). Prior research on heliostat canting and alignment strategies and optical defects, such as aberration and their impact on the resultant flux distribution at the receiver, showed the potential to further reduce spillage loss at CSP power tower plants.[41, 42] The ability to further reduce spillage loss while increasing concentration ratios and receiver temperatures requires a high degree of accuracy and alignment speed, which is well beyond current manual or partially automated techniques. Applicants should also consider how their proposed autonomous systems will interface with receiver operation.

[41] Sandia National Laboratories. *A Comparison of On-Axis and Off-Axis Heliostat Alignment Strategies.* https://www.osti.gov/servlets/purl/204230. 1996.
[42] Landman, W. and Gauché, P. *Influence of Canting Mechanism and Facet Profile on Heliostat Field Performance.* https://www.sciencedirect.com/science/article/pii/S1876610214004688. 2013.

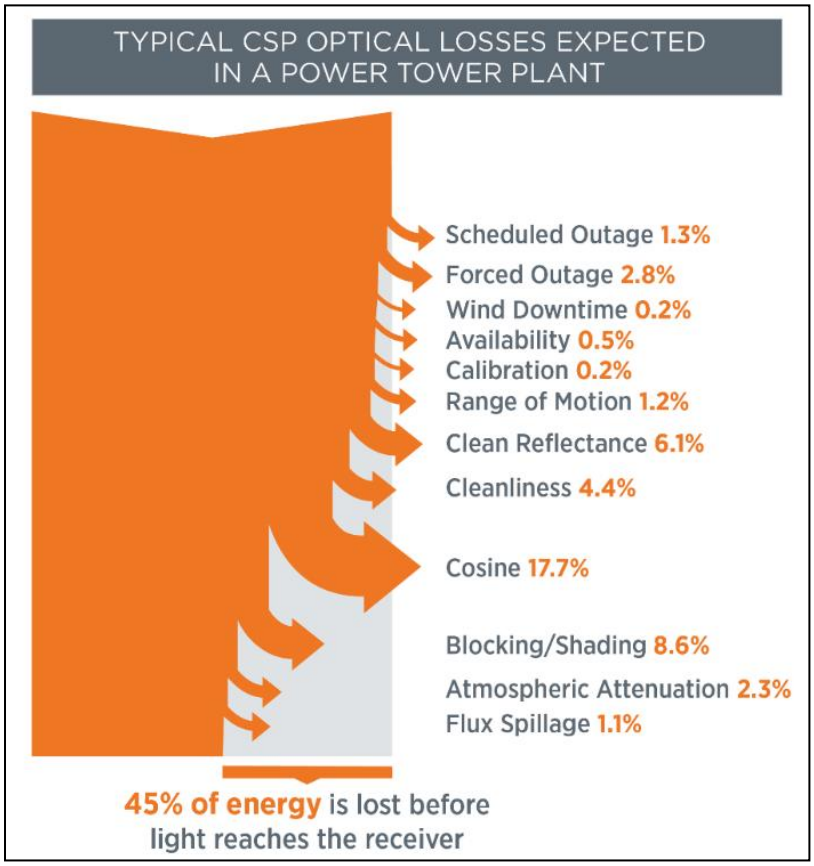

Figure 13. *Scenario showing standard CSP optical losses expected in a power tower plant*[43]

Successful autonomous solar field solutions should provide the level of accuracy and speed that can maximize collection efficiency while meeting the other SunShot 2030 solar field targets. Strategies to achieve this may include smart systems and internet of things–enabled components, which are potential solutions for faster communication and more accurate control of subsystems. Also included within this topic is the use of innovative field inspection technologies to optically survey and characterize a CSP collector field, which can be used as an input for autonomous controls. The emphasis for autonomous control is focused on power tower technology, but applications that show significant merit for autonomous control in other CSP plant configurations will also be considered.

For solutions that integrate with system-level control solutions for solar plants, like supervisory control and data acquisition, distributed control system, or programmable logic controllers, the project should address cybersecurity threats. These control architectures are typically segmented into hierarchal control levels

[43] National Renewable Energy Laboratory. https://sam.nrel.gov/

from production scheduling all the way down to subsystem- and component-level sensors. For any control and data acquisition system, inherent cybersecurity threats will need to be fully understood and addressed.[44] While plant-wide autonomous control is ideal, successful applications to this topic will address the lowest-level control functions, specifically for the solar field.

To further clarify the type of applications that will be encouraged, Table 3, below, gives examples of areas in which SETO has identified a need and potential solutions. The list is not exhaustive, and the solutions are only examples of possible strategies. Applicants responding to this section of the FOA need not be constrained by this list.

Current Status of Solar Field Technology	Possible Solutions
• Tracking error tends to increase over time and is typically manually corrected. • Heliostat positional accuracy degrades over time due to structural distortion, thereby requiring occasional recalibration of the heliostats. • Canting adjustment of heliostats are often labor-intensive and slow. • Mirror washing needs and frequency are usually estimated and not optimized. • Heliostats typically do not communicate with each other or the receiver. Wireless communication is not widely used in CSP plants.	• Design and demonstrate a fully autonomous solar field that can improve the speed of calibration at reduced costs, rapidly adjust canting and tracking errors, monitor mirror soiling, and apply automated washing. • Investigate and implement ideal physical and logical network topologies for efficient communication. • Autonomous inspection using unmanned aerial vehicles combined with smart communication can accurately and efficiently determine when mirror washing is needed. • Implement intelligent control techniques, such as fuzzy logic, neural network, genetic algorithm, or machine learning to remove the need for manual decision-making.

Table 3. *Collector needs where autonomous control can be implemented*

Applications to this topic can address one of the following:

1. Autonomous solar field subsystems, including: concepts for autonomous methods of controlling solar field tracking and canting or responding to environmental conditions, such as high winds, transient cloud cover, or soiling. Targeted metrics should contribute to a net increase of instantaneous optical efficiency by at least 5%, while showing a pathway toward meeting the other SunShot 2030 cost and performance targets for the solar field. Reasonable assumptions will need to account for a baseline scenario and

[44] *ISA Transactions.*"Cyber Security Risk Assessment for SCADA and DCS Networks." https://www.ncbi.nlm.nih.gov/pubmed/17624350. October 2007.

clearly quantify where improvements are made. Applications can address R&D and/or demonstration, as appropriate.

2. Full autonomous solar field system development. These applications should consist of a large, diverse team capable of proposing holistic solutions to improve solar field and receiver performance to enable a net increase of instantaneous optical efficiency by at least 5%, while showing a pathway toward meeting the other SunShot 2030 cost and performance targets for the solar field. Reasonable assumptions will need to account for a baseline scenario and clearly quantify where improvements are made. Applications should culminate in demonstrations at near-commercial conditions and scale.

Applications Specifically Not of Interest

- While applications may incorporate advanced solar forecasting methods, this topic does not solicit development of novel forecasting technologies.

iii. Topic Area 3: Balance of Systems Soft Costs Reduction

The balance of systems soft costs program works to reduce the costs associated with the non-hardware components of a solar system. These comprise direct costs of solar system project development, including those associated with siting; permitting (both building/construction and land permits); contracts; capital costs; grid interconnection; independent audit and compliance with local codes, rules and regulations; installation labor; and operations and maintenance. Soft costs can also take the form of indirect barriers to deployment that derive from a variety of factors including, but not limited to, local policy, overarching regulations, access to capital, and socioeconomic issues.

Although soft costs declined by 40% to 75% between 2010 and 2018 across residential-, commercial-, and utility-scale solar systems, hardware costs have declined even faster. As depicted below in Figure 14, this has resulted in an increasing share of softs costs relative to the total solar system cost.[45] The 2018 reduction in soft cost percentage across all three sectors was caused by increased module prices associated with increased tariffs.

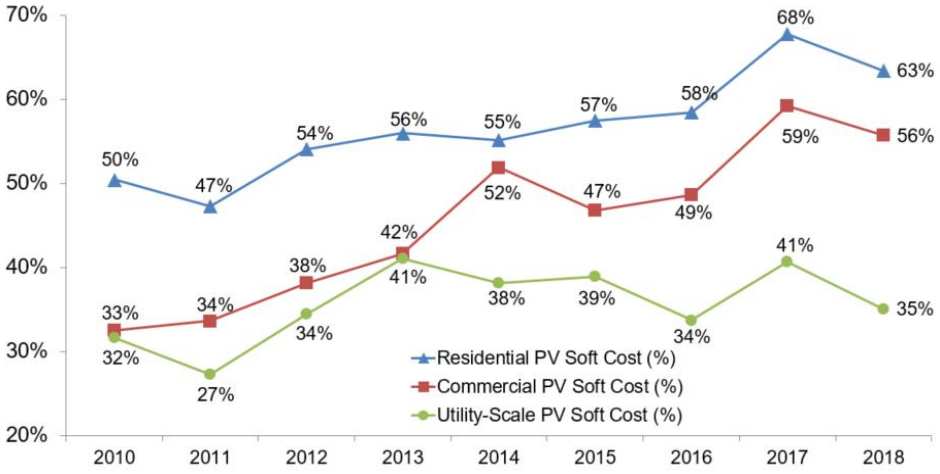

Figure 14. *Modeled trend of soft costs as a proportion of total cost by sector, 2010–2018*[46]

SETO addresses soft costs by working with a broad range of solar stakeholders to research, develop, and validate innovative approaches to overcome the hurdles referenced above including burdens that translate to costs paid by individuals,

[45] The increasing soft cost proportion in this figure indicates that soft costs declined more slowly than hardware costs over the period. It does not indicate that soft costs increased on an absolute basis.

[46] National Renewable Energy Laboratory. *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018*. https://www.nrel.gov/docs/fy19osti/72399.pdf. November 2018.

families, businesses, and manufacturers.[47] In particular, SETO has funded several programs aimed at addressing the specific soft cost drivers this topic area intends to target, including those associated with siting, permitting, interconnecting, and financing solar projects. These programs conducted fundamental research and analysis,[48] identified and replicated best practices,[49] and seeded innovative multi-stakeholder collaborations[50] while disseminating critical learnings to the solar industry. The industry has led efforts to streamline and standardize permitting, inspection, and interconnection (PI&I)[51] as well as provide informational resources[52] that can help with organized scaling. Despite these efforts, daunting PI&I issues remain, especially in new solar markets and with under-resourced utilities and authorities having jurisdiction (AHJ). Many governing bodies have a role in the regulation of solar projects, including more than 18,000 AHJs and 3,300 investor-owned, co-operative, and municipal utilities with unique requirements and protocols. There are opportunities to innovate, simplify, and streamline the processes by which these bodies interact with one another and the industry at large.

Given that solar businesses large and small operate in areas spanning multiple AHJs and utilities, reducing regulatory burden and associated costs requires the development and implementation of more efficient practices across regions or the broader United States. Of particular interest are PI&I challenges and related soft costs associated with the installation of solar-plus-energy-storage solutions, which are only just beginning to be characterized and quantified,[53] and managing cybersecurity concerns on the grid.

While addressing regulatory burdens should enable cost reductions for solar businesses and ultimately solar customers, SETO has also identified opportunities to increase solar affordability and expand the market through finance innovations. Several factors limit the solar market's ability to expand its customer base, including the high cost and up-front expense of PV systems, the lack of competitive interest rates, compared to a home equity loan or credit line, few options for those with a low credit score and/or income below traditionally acceptable underwriting criteria,

[47] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/soft-costs.
[48] For example, on the permitting of utility-scale solar that resulted in the publication of a Multiagency Avian-Solar Science Coordination Plan, which provides a framework for future research needed to support agency decisions regarding utility-scale PV and CSP project development.
[49] For example, the Solar Market Pathways and SolSmart programs.
[50] For example, the SunShot Prize: The Race to 7-Day Solar.
[51] For example, the Institute of Electrical and Electronics Engineers' Interconnection Standard 1547-2018 and permitting standards and best practices from the Solar America Board for Codes and Standards.
[52] For example, Interstate Renewable Energy Council's Interconnection Resources and SolSmart's Permitting Resources.
[53] National Renewable Energy Laboratory. *Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016.* https://www.nrel.gov/docs/fy17osti/67474.pdf. February 2017.

and the inability of tax-exempt businesses and certain low- and moderate-income populations to use the Investment Tax Credit. SETO supported the Solar in Your Community Challenge (Challenge) to develop innovative and scalable business and financial models that expand solar access by increasing affordability. More than 170 teams from 42 states, Washington, D.C., Puerto Rico, and Guam were selected to participate in the Challenge. They are developing and piloting new models to deploy inclusive solar projects, with participation from nonprofits and low-moderate income customers, within their communities. A critical piece of the equation illuminated by the Challenge and identified by research at the National Renewable Energy Laboratory[54] is the opportunity to increase the capabilities of local financial entities, such as community banks, credit unions, and community development financial institutions, to make decisions and finance projects in their communities that otherwise might have been passed over by conventional financial institutions.

As more consumers and companies adopt solar solutions, administrative costs related to PI&I and financing must be minimized. Building on prior SETO efforts, projects in this topic area will research, develop, and validate new approaches to reduce the regulatory burdens of solar energy development and increase the affordability of solar systems for consumers and businesses. All projects should be ambitious but achievable and define and quantify a clear need and rationale for federal support to accomplish their objectives. Applicants should describe prior relevant efforts both within and outside their organization and emphasize the ways in which their project will build upon those results. Plans to tie in to and expand current ongoing efforts are also of interest. Projects should also include a clear path to testing the scalability and/or replicability of the solution, including a plan to sustain and scale those activities post-award. The types of entities needed to replicate the project should be identified in the application, but specific partners can be researched and identified once the project is underway.

Areas of Interest for Applications to Topic Area 3

This topic intends to support projects that fall under one of the following topics:

- **Topic Area 3.1: Collaborative Partnerships to Address Regulatory Burdens**: Data-driven approaches to addressing regulatory burdens by assembling large stakeholder groups at a regional or nationwide scale, with particular attention to new and developing solar markets, through innovative public-private partnerships, accelerator concepts, or other mechanisms
- **Topic Area 3.2: Data Collection Methods to Assess Avian Impacts**: Research projects to improve data collection methodologies for cost-effectively determining how utility-scale PV installations and/or CSP plants affect birds, assessing the effectiveness of mitigation technologies or techniques, and establishing a mechanism to share avian-solar data

[54] NREL/TP-6A20-71753

- **Topic Area 3.3: Increasing Solar Affordability through Innovative Solar Finance**: Stakeholder and analytical approaches to expand solar access by developing new financing tools and/or mechanisms that can, for example, help local financial institutions, such as community banks and credit unions, deploy their capital toward solar energy projects in their communities
- **Topic Area 3.4: Rapid Solar Software Development**: Research and development of first-of-a-kind products or tools leveraging new and emerging software capabilities that address critical challenges associated with solar soft costs for residential, commercial, and industrial solar-energy customers

1. Topic Area 3.1: Collaborative Partnerships to Address Regulatory Burdens

This topic area encourages collaborative work between various jurisdictions and private-sector facilitators to develop comprehensive, sustainable solutions that can be applied to other parts of the country. Teams should consider including local community organizations, solar developers, technology developers, trade associations, and other key stakeholders as they explore and test innovative strategies and mechanisms to address regulatory burdens during solar project development. This topic is open to regional and nationwide approaches, with particular attention to new and developing solar markets.

Approaches may involve the development and validation of innovative public-private partnership models, accelerator concepts, or other mechanisms. Partnerships involving multiple stakeholders are specifically encouraged. Teams should have the relevant diversity of skills to address these issues and engage entities with the capacity and resources to replicate successful innovations in other localities and jurisdictions. A pilot of an innovative solution within a single AHJ is not of interest. A project may involve testing novel approaches in pilot locations, assessing the results, and then replicating successful outcomes in other jurisdictions. Applicants can propose to leverage internal resources and analytical support from national laboratories or relevant experts during their award period. Applicants should consider the role of data collection, analysis, and dissemination when developing their projects. While software could be an element of a proposal to this topic area, applicants who solely want to develop software solutions with potential commercial or analysis applications should consider applying to Topic Area 3.4.

SETO is interested in receiving collaborative partnership applications that focus on one of the following areas:

a) Rooftop solar and solar-plus-energy-storage permitting, inspection and interconnection challenges:

Projects should seek to develop novel approaches to expedite the PI&I of residential and commercial solar and solar-plus-energy-storage installations.

Projects may attempt to address PI&I challenges in adjacent geographic areas or regions where solar energy businesses in those areas normally operate. A project may address permitting and inspection or interconnection challenges separately; it does not have to address both. Projects may seek to develop solutions for integrated PI&I processing where those opportunities exist, perhaps in jurisdictions with municipal utilities. Solutions should consider the implications of their PI&I acceleration on the quality of installation and the safety of the installed system.

Projects could consider including one or more of the following approaches and tools: solutions that leverage permitting platforms already in use by relevant stakeholders; analytical support to local entities from national laboratories or other qualified experts; training and credentialing programs; streamlining the use of standard system designs; innovative and efficient processing solutions for PI&I applications; and/or other innovative solutions to reducing PI&I burdens.

b) **Large-scale ground-mounted solar PV and CSP siting, permitting, and environmental impact:**
Projects should seek to address siting and permitting barriers to deploying utility-scale ground-mounted solar, including those associated with land use and zoning, as well as equity concerns, such as whether to use land for agricultural or energy production. In the context of federal lands, projects may build upon groundwork laid in 2012, with the update to Bureau of Land Management solar policies that allows more efficient and standardized permitting for projects larger than 20 megawatts in six southwestern states[55] and the competitive leasing rule issued in 2016.[56]

SETO is interested in collaborative projects that bring together public- and private-sector stakeholders from relevant jurisdictions, including representatives from governing bodies, to develop and pilot new approaches to facilitate the siting, land permitting, and environmental review of large-scale solar projects. Topics of interest include:

- Zoning methodologies and best practices
- Co-siting of solar with brownfields, airports, wastewater treatment facilities, bodies of water (like reservoirs), and land used for agriculture
- Enhancing the ecological value of large-scale solar deployment, reducing land use impacts, and facilitating co-benefits

[55] U.S. Department of the Interior Bureau of Land Management Solar Energy Program. http://blmsolar.anl.gov/.
[56] U.S. Department of the Interior Bureau of Land Management. "Department of the Interior Finalizes Rule Providing a Foundation for the Future of BLM's Renewable Energy Program." https://www.blm.gov/node/7653.

- Considerations regarding site preparation, operations and maintenance practices (such as PV in the presence of farms[57]), and implications of various site designs
- Urban and rural planning implications related to the development of community solar systems
- For CSP specifically, precompetitive designs and minimum technical requirements for plant components, such as thermal energy storage or collector fields, that could facilitate siting and permitting and ultimately improve bankability of these plants

Projects should seek to develop novel scalable approaches to address siting, permitting, and environmental impact challenges associated with large-scale PV and CSP deployment. New approaches and tools may include development of plans and road maps to streamline processes and overcome challenges; analytical support to local entities from national laboratories or other qualified stakeholders; and stakeholder processes to collect and analyze data that can inform the development of best practices and decision tools.

c) Addressing solar cybersecurity challenges:
Projects seeking to develop technological solutions to decrease the cybersecurity risks of solar systems on the grid should refer to Topic Area 5.3: Advanced PV Controls and Cybersecurity.

Projects should seek to develop strategic plans, road maps, best practices, and other decision-making tools that can enable cybersecurity solutions while addressing potential regulatory controls and costs. As solar technologies and other distributed energy resources[58] (DER) become internet-connected, they pose technical and operational cybersecurity challenges. These challenges may also pose increased regulatory controls and costs.

SETO is seeking applications that aim to facilitate an encompassing, forward-looking approach to the role of solar and related technologies in the broader grid, cybersecurity, and privacy fields. Applicants should identify and leverage existing and ongoing cybersecurity efforts to ensure their efforts are not duplicative. Results of these projects should help inform relevant decision-makers on how to consider cybersecurity when developing plans to address the issues. Successful applicants must be well positioned to convene cybersecurity

[57] *Delmarva Now.* "Family: Agriculture and Solar Farms Can Coexist." https://www.delmarvanow.com/story/news/local/virginia/2016/10/10/sheep-agriculture-solar-farm/91785066/. October 10, 2016.
[58] DER are small-scale energy resources connected to the distribution system, including but not limited to solar PV, wind, flexible loads, energy storage technologies, electric vehicles, and combined heat and power.

experts and solar-industry representatives alongside decision-makers in the policy and utility spheres. Projects should look to adjacent fields to identify relevant best practices and leverage related efforts.

d) Other soft cost drivers:

SETO welcomes applications from teams of applicants to address other solar soft costs, develop solutions for challenging market segments, and explore opportunities to leverage public-private partnerships to enable streamlined installation of solar energy and synergistic technologies like energy storage. Applicants should clearly and concisely describe the soft cost barrier(s) that will be addressed, discuss how their solution addresses their chosen soft cost, and explain why and how their team is positioned to make impactful progress on that soft cost. Solutions should focus on bringing together all relevant public and private entities as a team to address the chosen soft cost(s).

Applications Specifically Not of Interest

- Applications that include the use of award funds for lobbying activities at the federal, state, or local level

2. Topic Area 3.2: Data Collection Methods to Assess Avian Impacts

This topic seeks projects that reduce the costs of siting utility-scale solar power plants associated with environmental permitting, compliance monitoring, and impact mitigation. In particular, these projects will help reduce the cost of collecting data necessary for assessing the potential impact of a solar plant on avian populations or the effectiveness of mitigation strategies.

The objective of this topic is to develop and validate innovative methods or technologies that can decrease the cost of collecting and sharing data on avian interactions with utility-scale PV, including floating PV systems, and/or CSP facilities, while meeting quality standards for regulatory compliance. Specifically, this topic aims to:

- Develop and validate novel data collection methods or technologies that can cost-effectively assess avian-solar interactions
- Develop and validate novel data collection methods or technologies that can cost-effectively assess the effectiveness of avian impact mitigation technologies and techniques
- Establish a data-sharing mechanism for avian data collected at utility-scale solar PV and CSP plants

Proposed approaches to data collection and analysis can be used to assess both avian-solar interactions and mitigation strategies. Projects must include partners that enable real-world testing and verification of the proposed data collection

method or technology. Applications must include an assessment of how the proposed method or technology can reduce avian data-collection costs. Applications that can address avian data collection and sharing needs throughout the United States are encouraged. Applicants may consider previous efforts of the Multiagency Avian-Solar Collaborative Working Group[59] and the broader industry Avian-Solar Working Group[60] when developing a proposal to this topic area.

For projects proposing a data-sharing mechanism, applicants must include a sustainability plan for funding the operation and maintenance of the proposed mechanism beyond the end of the project. Applications should describe how the proposed data-sharing mechanism will be useful for, and widely used by, stakeholders.

Applications Specifically Not of Interest

- Projects using a method or technology commonly used at solar plants to collect avian data, such as surveying transects for carcasses or feather spots

3. Topic Area 3.3: Increasing Solar Affordability through Innovative Solar Finance

This topic area seeks to address the problem of high financing costs that make solar unaffordable for some consumers and limit the solar market's ability to expand its customer base. Projects should enable local financial institutions, such as community banks, credit unions, and community development financial institutions, to fund solar projects in their local communities.[61] By leveraging their knowledge of lending at the local level, and applying metrics other than credit scores to assess a customer's repayment ability, these projects will leverage new financing instruments so that local institutions can help increase access to affordable solar energy for businesses and individuals in low- and moderate-income communities.

This topic will support stakeholder and analytical approaches to increase solar affordability and expand solar access by developing new financing tools and/or mechanisms to help local financial institutions deploy their capital toward solar energy projects in their communities. SETO is interested in projects that develop new methods to evaluate creditworthiness or reduce the cost of capital, deploy data and/or tools to create new risk-mitigation techniques, or develop mechanisms to leverage incentives and create solutions to take advantage of burgeoning areas,

[59] A federal and state agency working group that developed a framework for future research needed to support agency decisions regarding utility-scale solar development. http://blmsolar.anl.gov/program/avian-solar/.
[60] A working group comprised of utility-scale PV industry, environmental organizations, and academics convened to advance independent and coordinated scientific research to better understand how birds interact with solar facilities. http://www.aviansolar.org/.
[61] National Renewable Energy Laboratory. *Solar Lending Practices by Community and Regional Financial Institutions.* https://www.nrel.gov/docs/fy18osti/71753.pdf. June 2018.

such as opportunity zones.[62] Also of interest are projects that provide technical assistance and education for local institutions and municipalities in new and developing solar markets who may need help implementing best practices and solutions developed by entities with more resources.

Projects may involve the development of collaborative public-private partnership models and may address topics such as community solar design, community economic development and reinvestment, revolving infrastructure fund development, or incentive program design. Models that successfully leverage federal and local incentives, energy assistance programs, and other mechanisms such as opportunity zones, may help provide a suite of inclusive finance solutions and accelerate solar energy's growth for individuals, communities, or businesses.

Successful applications will include a description of a new financial mechanism, the relevant stakeholders, a plan for a pilot study, and its evaluation. Solutions should be replicable and scalable, and recipients should include a dissemination strategy for translating these solutions to similar entities and peers during the award period. Applications should describe how relevant data will be gathered and analyzed to prove the long-term viability and affordability of any product for the end user.

4. Topic Area 3.4: Rapid Solar Software Development

This topic area is structured to provide award recipients with the seed funding needed to research, develop, and validate specific new software products or tools. Projects will create first-of-a-kind products or tools leveraging new and emerging software capabilities that address critical challenges associated with solar soft costs for residential, commercial, and industrial solar-energy customers.

Proposed solutions should have a clear and compelling case for how it will help drive down solar soft costs using new technological and data-driven pathways. The application should clearly identify the soft costs to be reduced and show an understanding of how that soft cost impacts overall system costs. Projects should be designed to produce significant results within one year of performance through the use or generation of novel and emerging software solutions.

This topic is open to for-profit companies as well as nonprofit organizations, universities, and national labs to develop new software tools and/or modules or create new capabilities in existing tools. Applicants are encouraged to consider the development of open access or open source solutions where appropriate.

Applications Specifically Not of Interest

[62] Internal Revenue Service. "Opportunity Zones Frequently Asked Questions." https://www.irs.gov/newsroom/opportunity-zones-frequently-asked-questions.

- Concepts proposing standard tools relating to conventional lead generation and customer acquisition
- Concepts proposing end-to-end platform development for system design and sales
- Concepts proposing products and solutions that are not significantly different from those already established in the market

iv. Topic Area 4: Innovations in Manufacturing: Hardware Incubator

Projects seeking to develop innovations in concentrating solar power manufacturing should refer to Topic Area 2.2: Materials and Manufacturing.

The innovations in manufacturing program supports the transformation of research and development results into solar products that can be manufactured in the United States. This work addresses key barriers to bringing a commercial solution to market while encouraging private-sector investment. Since its inception in 2007, 129 startup companies have received awards to participate in SETO's Incubator program, working to develop and launch transformative solar hardware products and services.

The solar office seeks to fund innovative product ideas with a clear pathway to reduce solar electricity costs that are too risky for private investment but have the potential for rapid commercialization. Projects will support high-impact research and development at for-profit companies that will be well positioned to attract private sector investment. SETO is particularly interested in applications for the development of innovative and impactful technologies that will support a strong U.S. solar manufacturing sector and supply chain, which can produce cost-competitive solar components that keep pace with the rising domestic and global demand for affordable solar energy.

An ideal applicant would start with an existing early-stage prototype that can demonstrate some functionality in a controlled environment. Through this award, the awardee would advance that prototype to a manufacturing and commercially relevant prototype, meaning the research will seek to prove all functionality using pre-commercial manufacturing techniques. It would not advance a product to an automated-manufacturing stage. The project should be structured to answer critical questions required to reduce the associated technical and business risks.

Applications should fall within one of these areas:

a) Advanced solar system integration technologies: Responsive applicants would advance the prediction, monitoring, and control of solar power production and distribution and the capabilities of power electronics.
b) Concentrating solar-thermal power technologies: Responsive applicants would develop technologies or components of technologies that focus sunlight to generate and store high-temperature heat for electricity generation and other end uses, such as desalination or industrial-process heat.
c) PV technologies: Responsive applicants would improve PV system reliability; improve performance of novel PV materials and components to increase annual energy yield; develop novel PV panel manufacturing technologies, including module-manufacturing methods that enable incorporation of new

cell technologies, such as perovskite or other high-efficiency solar cells; reduce supply-chain capital expense; or develop metrology and characterization tools to advance the efficiency and reliability of PV systems in the field.

d) Technologies or solutions that use a hardware solution to reduce the balance-of-system cost of a PV system, including hardware costs and soft costs such as installation labor.

A responsive application to this topic should include some or all of the following information:

- Technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative
- Projections for price and/or performance improvements that are referenced to a benchmark
- A clear assessment of the state of the art, including existing commercially available products or solutions that could be considered competitors, and how the proposed technology would represent a significantly different and competitively sustainable improvement
- Supporting documentation that validates the value proposition of the proposed solution
- A preliminary cost analysis showing a path to becoming cost-competitive with the ever-evolving state of the art
- Justification of all performance claims with theoretical predictions and/or relevant experimental data
- Explanation of the impact of federal funds on the development of the solution, why private-sector funding has been difficult to secure, and efforts by the applicant to date to secure funding
- Description of how addressing the technical risks identified in the application will increase the likelihood of securing private investment following the award period

The topic is *not* intended to fund the following:

- The creation of a product, organization, service, or other entity or item that requires continued government support
- Any work that is duplicative with other federally funded research on the same technology at the same technology-readiness level
- Large-scale demonstration or deployment of solutions that do not require further research and development, unless field testing and early-stage pilots are part of the technology research and development cycle
- Concepts that solely rely on a licensing model

Applications Specifically Not of Interest

- Projects that do not have a significant hardware research and development effort
- Proposed technologies that are not based on sound scientific principles, such as anything that violates the laws of thermodynamics
- Undifferentiated products, incremental advances or duplicative products
- Solutions in which solar is not a major component of the technology
- Products or solutions for systems which cannot tie to the electric grid, such as wholly off-grid applications
- Software to facilitate system design, system monitoring, or customer acquisition

v. Topic Area 5: Advanced Solar Systems Integration Technologies

The systems integration program supports early-stage research, development, and demonstration that advances the reliable, resilient, secure, and affordable integration of solar energy onto the U.S. electric grid. As solar energy generation on the grid increases, it is necessary to identify the associated technical, economic, and regulatory challenges, and develop solutions that both ensure compatibility with the existing grid and enable a smooth transition to a secure, reliable, and resilient grid of the future.

The nation's electricity grid infrastructure was built on large-scale, centralized generation located far from consumers who had little interaction with it. It relied on centralized control structures, and integrated minimal renewable generation and energy storage. This infrastructure is not well suited for the nation's current needs. A modern grid must integrate diverse generation and energy-efficiency resources, including those that are customer-sited and variable, while ensuring reliable power. It must also be dynamic and integrate sensor data to better satisfy customer demand and detect and mitigate disturbances. Finally, it must provide strong protection against physical and cyber risks.

A business-as-usual trajectory for the U.S. electric infrastructure will not result in a timely transition to a modernized grid.[63] Since prior investments in the electric grid will remain in service for decades, the United States must smartly invest in forward-looking technologies that will support the creation of advanced grid infrastructure. There is a critical need to foster innovations and new technology adoption.

The U.S. Department of Energy Grid Modernization Initiative[64] is a crosscutting effort that aligns grid modernization efforts across multiple DOE program offices. As part of the initiative, SETO's systems integration program supports targeted technology R&D that addresses the technical challenges with achieving higher solar penetration, while supporting a safe, reliable, secure, and cost-effective electric power system. These research activities are aligned with the key technology areas identified in the Grid Modernization Multi-Year Program Plan,[65] such as grid resilience, energy storage, sensors and measurements, and cybersecurity. Solar energy plays an important role in advancing each of these technology areas, enhancing grid modernization in the process.

[63] U.S. Department of Energy Grid Modernization Multiyear Program Plan. https://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp.

[64] U.S. Department of Energy Grid Modernization Initiative. https://energy.gov/under-secretary-science-and-energy/grid-modernization-initiative.

[65] U.S. Department of Energy Grid Modernization Multiyear Program Plan. https://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp.

SETO's systems integration research focuses on using solar energy for greater grid resilience and improved reliability. This will be accomplished through advancements that enable effective operations with increasing penetration of solar energy; advanced dynamic photovoltaics (PV) models and adaptive distribution protection; interconnecting and integrating solar with energy storage and synergistic technologies to provide grid services; researching advanced inverter controls and sensors; and supporting processes for standardizing interconnection, interoperability, and cybersecurity for PV. The goal is to advance the knowledge base as well as the ability to integrate increasing amounts of solar generation into electric transmission and distribution systems in a cost-effective, secure, resilient, and reliable manner.

Areas of Interest for Applications to Topic Area 5

Higher penetration of solar generation poses challenges for various operational time scales and for grid planning. However, solar and other DER also provide opportunities to advance the grid into a more interactive, resilient, and flexible paradigm.

As the penetration of PV on the grid grows, state-of-the-art dynamic models have failed to predict responses by power systems and PV plants to extreme events, as observed recently by the North American Electric Reliability Corporation,[66,67,68] which analyzed disturbances where inverter-based generation went off-line. Research on advanced dynamic PV models and adaptive protection could help prevent such disturbances and increase grid reliability and resilience.

Distributed generation could help supplement grid services offered by independent system operators while providing diversity and resilience. Research shows that utility-scale PV plants can react quickly to load changes and can have regulation accuracy that is nearly 30% higher than conventional generation plants, delivering system-wide benefits. Research is needed to investigate whether aggregation of small-scale PV can achieve similar results.

---

[66] North American Electric Reliability Corporation. *1200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report.* https://www.nerc.com/pa/rrm/ea/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_Interruption_Final.pdf. June 2017.

[67] North American Electric Reliability Corporation. *900 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report.* https://www.nerc.com/pa/rrm/ea/October%209%202017%20Canyon%202%20Fire%20Disturbance%20Report/900%20MW%20Solar%20Photovoltaic%20Resource%20Interruption%20Disturbance%20Report.pdf. February 2018.

[68] North American Electric Reliability Corporation. *April and May 2018 Fault Induced Solar Photovoltaic Resource Interruption Disturbances Report.* https://www.nerc.com/pa/rrm/ea/April_May_2018_Fault_Induced_Solar_PV_Resource_Int/April_May_2018_Solar_PV_Disturbance_Report.pdf. January 2019.

Finally, grid operators have had little information and control over the distributed and behind-the-meter (BTM) solar generation on distribution networks, because of the lack of sensors and their integration into the existing operational tools. Research for grid-edge sensors and their cyber-secure integration is needed to mitigate the challenges posed by small-scale distributed generation. Additionally, more advanced understanding of grid-forming inverters (see Topic 5.3.b for a detailed description) could improve the resilience of the grid.

The systems integration program seeks to fund research in the following topic areas:

- **Topic Area 5.1: Adaptive Distribution Protection** – Hardware and software solutions that can dynamically respond to disturbances within an electrical system with high penetrations of solar energy and DER
- **Topic Area 5.2: Grid Services from Behind-the-Meter Solar and Other DER** – Solutions that would enable solar and other DER to provide grid services like load balancing and frequency control
- **Topic Area 5.3: Advanced PV Controls and Cybersecurity** – Technologies that enhance the visibility and control of PV inverters and sensors while improving the security of those devices from cyberattack

Within the context of Topic 5, DER[69] is defined as small-scale energy resources connected to the distribution system, including but not limited to solar PV, wind, flexible loads, energy storage technologies, electric vehicles, and combined heat and power.

Projects that pursue demonstration must meet the cost share requirements as described in Cost Sharing. Topics that require demonstration include Topic Areas 5.1 and Topic Area 5.3. For projects in Topic Area 5.2, demonstration is encouraged but optional.

All applications should focus on overcoming high PV penetration integration challenges, identified as 50% solar penetration or more compared to peak load on the distribution feeder system. Awarded applicants will be required to submit a cybersecurity plan as part of their project. The SETO systems integration program requires stringent performance metrics to be met by all applicants, which are defined within each topic. Applicants must address these performance metrics whenever applicable and are encouraged to add more whenever possible.

1. Topic Area 5.1: Adaptive Distribution Protection

[69] North American Electric Reliability Corporation. *Distributed Energy Resources: Connection Modeling and Reliability Considerations.* https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf. February 2017.

This topic is intended to support research, development, and demonstration of adaptive protection solutions for distribution power systems with high penetration of PV and DER. Adaptive protection solutions can identify faults within the electrical system and dynamically respond to those disturbances. SETO seeks to fund two interrelated technical approaches: (a) advanced modeling of dynamics of solar inverters and PV plants during disturbances and (b) innovative, scalable software and hardware protection designs for distribution systems with high solar penetrations. This effort will complement the system protection R&D in the U.S. DOE Office of Electricity Delivery and Energy Reliability by addressing the unique technical challenges with solar grid integration. Applications may respond to one or both research areas.

A. Advanced Dynamic Models for Smart Inverters

This research area is intended to advance models that will better predict power system and PV plant responses to extreme events, like potential grid instability issues when too much inverter-based generation goes off-line. The first main objective of this research area is to develop and validate advanced modeling of smart inverters to enable accurate and fast analysis of the dynamic response of individual, aggregate, or utility-scale PV systems. The second main objective is to provide better understanding of the dynamic behaviors of inverters with advanced control functions and their interactions with bulk power systems, distribution systems, and microgrids. The proposed PV system dynamic models should be standard to enable industry-wide adoption.

Applications should define the state-of-the-art dynamic models for either an individual PV inverter, an aggregation of distributed PV inverters at different levels, or a utility-scale PV plant connected to a bulk power system or distribution network. Successful projects should detail proposed enhancements to one or more of these models, including but not limited to:

- Reduced-order models that do not compromise accuracy for fast analysis
- Hi-fidelity models that better represent the dynamic behaviors under fault or extreme events
- Original and unique new models that integrate some of the smart inverter functionalities

In addition, successful projects should:

- Clearly define model assumptions and limitations. The new model(s) should integrate seamlessly with numerical analysis of grid simulations and/or hardware-in-the-loop testing.

- Be validated against standard test cases, applicable North American Electric Reliability Corporation Major Event Analysis Reports,[70] simulated data, or field measurements. New models should be compared to the state of the art and demonstrate significant increases in performance metrics, as defined by the applications.

Applications are encouraged to meet the following performance metrics:

Positive sequence root mean square model	> 95% accuracy in terms of rate of change of frequency and frequency deviation at nadir and settling frequency, reasonable match in response shapes within 4 minutes after disturbance in disturbance-based verification.
Electromagnetic transient model	Model outputs match actual response up to 8 seconds after disturbance

Applicants may propose innovative approaches for dynamic PV inverter model validations, including aggregate model validation or accurate online model validation. Projects that propose model parameters that set selections and calibration are also of high interest.

Demonstrations or simulations must illustrate the applicability of proposed models to one or more of the following: transmission and distribution interconnection stability studies, including small signal and large signal stability analysis; electromagnetic transients study; balanced and unbalanced short circuit current calculations for fault analysis, protection, or weak grid identification; power quality analysis; fault ride-through; and frequency response and ramping studies.

Applications Specifically Not of Interest

- Applications that do not include PV inverters
- New inverter designs and associated model changes
- Black-box models that cannot be integrated into industry software and models

B. Adaptive Protection for Distribution Grids

This research area seeks to fund enhanced power system protection solutions for distribution grids with high penetrations of PV and other DER that would isolate electrical power systems from faults by disconnecting the faulted parts from the electrical network. The main goal of this research area is to develop and field-

[70] North American Electric Reliability Corporation. "Major Event Analysis Reports." https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx.

validate effective and scalable adaptive protection solutions to enhance system reliability and resilience, with an emphasis on software.

Successful projects will develop adaptive protection solutions that can keep the power system stable by isolating the faulted components while being able to actively change settings and functionality relative to changing system operations.

The primary objective is to develop protection solutions that:

- Propose adaptive protection designs applicable to different conditions and wide system applications, such that they are adjustable, resettable, and controllable
- Focus on adaptive protection for sub-transmission, distribution, and/or microgrids to maximize grid reliability and use PV for resiliency
- Support high variability of available fault current/voltage magnitude, angle, direction, and sensitivity
- Enable reverse power flow from DER and accommodate multiple DER types for multiple inverter fault-ride-through conditions and coordination with utility auto-reclosers
- Provide effective variable zone settings and address complexity issues for multi-zone protection schemes, taking into account upstream protection functionality that mitigates sympathetic tripping, and demonstrate effective risk management
- Address challenges relating to how today's inverter-based resources provide limited and varied fault current, and only positive sequence fault current
- Operate under unbalanced faults and grid topology changes, including operation in loop or meshed configurations
- Are economical in terms of cost, placement optimization, and functionalities
- Are tested and validated via control-, then power-hardware-in-the-loop (CHIL, PHIL), and then field-trialed
- Contain smart protection that can proactively adjust to high distributed solar generation

The secondary objectives of this research area include advancing fault detection and location algorithms, specifically for difficult cases such as line-to-line faults or topology changes with significantly varied DER fault current contributions. Applications should also define how the methodologies address changing loads, such as how reactive loads and power electronics-based loads behave during faults. Furthermore, applications should consider the potential impacts to operation under frequency/voltage load shedding, or remedial-action in addition to fault-induced delayed voltage recovery.

These applications should provide a detailed description of state-of-the-art distribution-grid protection engineering, proposed advancements, and R&D details, including:

- How the solution will meet baseline performance metrics for reliability, stability, sensitivity, selectivity, and timeliness, and any planned improvement—at least baselined against past reliability performance for the proposed field trial location, and measured using standard quantitative metrics such as the IEEE 1366 – IEEE Guide for Electric Power Distribution Reliability Indices[71]
- Any proposed dependence and development of communications-based functionality, such as peer-to-peer capabilities, and precision timing functionality
- Any monitoring and auxiliary functions
- Any changes to PV inverter protection and controls, especially under fault conditions and given that today's inverters generally provide less fault current and little or no zero-sequence and negative-sequence content

Applications should describe hardware and/or software development, with preference for developing adaptive protection algorithms and controls for the cyber-physical grid, meaning both the software and controls on the grid, as well as the wires and other physical components of the grid. Emphasis should be on electromagnetic power systems and PV real and reactive power flow interactions rather than cyber disturbances. Software solutions must specify whether they are for real-time performance or off-line simulations.

Areas of interest include but are not limited to:

- Protection algorithm development, such as advancement for setting-less relays; focused directional, single-point traveling waves; and incremental distance relays
- Protection during DER support of black start[72] and cold load pickup[73]
- Modular, combined alternating current (AC) and direct current (DC) protection
- Microgrid and distribution feeder medium voltage (MVDC: 1kV – 100kV) protection with high solar PV penetration and scenarios; microgrid multiple-points-of-common-coupling islanding for grid-connected mode and islanded mode protection

[71] Institute of Electrical and Electronics Engineers Standards Association. "IEEE 1366-2012 - IEEE Guide for Electric Power Distribution Reliability Indices." https://standards.ieee.org/standard/1366-2012.html.

[72] North American Electric Reliability Corporation. Glossary of Terms Used in NERC Reliability Standards. https://www.nerc.com/files/glossary_of_terms.pdf. Updated July 3, 2018.

[73] Institute of Electrical and Electronics Engineers Power System Relaying and Control Committee. *Cold Load Pickup Issues.* http://www.pes-psrc.org/kb/published/reports/Cold_Load_Pickup_Issues_Report.pdf.

- Automatic detection of missed protection coordination
- Mitigation of unintentional islanding risk by inverter-based generation, especially solar PV

Applications Specifically Not of Interest

- Project designs for DER power electronics, such as PV inverters or converters
- DER power electronics controls: applications focused primarily on inverter/converter model development for operation under grid fault conditions should be submitted to the PV modeling topic
- Ideas focused primarily on solid-state protection hardware designs
- Bulk power system protection and control for transmission systems
- Small or narrowly focused microgrid protection, such as residential microgrids and other single point-of-common-coupling microgrids
- Narrowly focused ideas related to updating relevant standards, such as IEEE C37.230
- Cybersecurity or physical device protection
- Projects with marginal involvement of high PV penetration

2. Topic Area 5.2: Grid Services from Behind-the-Meter Solar and Other DER

This topic supports research, development, and validation of grid services by BTM solar co-located with other DER through innovative approaches for smart control and optimization technologies. Grid services are generally activities grid operators perform to maintain and improve the power flow and quality of electricity on the grid. These services have historically been performed by central generators and facilitate the basic operation of electricity generation, transmission, and distribution and can spread across a wide range of time scales.[74,75,76] Existing research demonstrates the viability of using utility-scale PV generation to provide certain grid services.[77] The main objective of this topic is to research and develop grid services using small-scale solar generation and other DER technologies, potentially through aggregation of different BTM DER using local controls.

SETO will collaborate with other offices within EERE, particularly the Building Technologies Office and the Vehicle Technologies Office, to ensure synergy and alignment with the broader Beyond Batteries vision. Beyond Batteries is an EERE-

[74] Pacific Gas and Electric. *Enabling Smart Inverters for Distribution Grid Services.* https://www.pge.com/pge_global/common/pdfs/about-pge/environment/what-we-are-doing/electric-program-investment-charge/Joint-IOU-SI-White-Paper.pdf. October 2018.

[75] *IEEE Power and Energy Magazine.* "Maintaining Balance: The Increasing Role of Energy Storage for Renewable Integration." https://ieeexplore.ieee.org/document/8070540. November–December 2017.

[76] Pacific Northwest National Laboratory. "Grid Architecture: Advanced Concepts." https://gridarchitecture.pnnl.gov/advanced-concepts.aspx.

[77] National Renewable Energy Laboratory. *Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant.* https://www.nrel.gov/docs/fy17osti/67799.pdf. March 2017.

wide initiative to develop new technologies and analytical tools that improve grid reliability through increased flexibility and grid services from renewable generation, load management, and alternative storage technologies.

Demonstration of proposed services will be supported for cases where there is an existing market or other mechanism that can accommodate such services, and where the projects conform to the grid operator's requirements and specifications. In those cases, the participation of a grid operator—either the balancing authority or distribution utility—is strongly encouraged.

This topic solicits technologies for the distribution system planning and operations that could enable the development of new market products. The grid services supplied by DER would be based on the exchange of real and/or reactive power between the DER devices and the electric grid in order to improve the reliability and resilience of the grid, reduce the cost of energy, and ease the planning and maintenance of the grid. Solutions should encourage the use of different types of DER and consider any consequences on adjacent systems or customers.

The proposed solutions should provide detailed state-of-the-art definitions for grid services supported by DER, especially PV, that are deployed or in the process of being adopted. Successful projects will consider existing research that demonstrates the viability of using utility-scale PV generation to provide certain grid services.[78] Projects may focus on any number of areas, including but not limited to:

- System peak capacity management by reducing net load as needed so that it never exceeds grid capacity. These applications should demonstrate reducing the need for capital expenditure to expand or upgrade generation, transmission, or distribution capacity.
- Technologies for PV participation in supply capacity products offered by independent system operators. These applications should demonstrate sufficient regional generation capacity, typically through reserve capacity, for unplanned events lasting up to two hours.
- Providing frequency regulation by managing generation and load to restore balance between supply and demand in response to an interval signal from the grid operator that lasts about four seconds. These applications should demonstrate maintaining grid frequency within an acceptable range in the face of continual, minute-long imbalances between supply and demand.
- Providing ramping capability that demonstrates managing the output of total generation to maintain balance between supply and demand in response to rapid changes in power production by renewables.
- Providing primary frequency response by remaining on standby, ready and able to detect when grid frequency drops within one second. These

[78] Ibid.

applications should demonstrate the capability to slow and stop the otherwise precipitous change in frequency due to unexpected trips of large resources or loads off-line.

- Developing a suite of distribution-level near-real-time grid services similar to those used in the bulk power system. These services are especially critical in establishing and maintaining system frequency and voltage, and balancing generation and demand for islanded grid or microgrid configurations in which solar is the dominant local generation source.
- Assisting in distribution voltage management by remaining on standby, ready and able to respond to rapid changes in distribution voltage, and act instantly by rapidly adjusting net load, within one second, in the form of its reactive and/or real power components.
- Assisting in black start, islanding, and resilience for faster restoration of local power service, and preventing and mitigating social emergencies, large financial losses, and possible loss of life.

Applications should include performance metrics that are likewise defined with respect to the state of the art for the proposed grid service(s).

Applications Specifically Not of Interest

- Grid services provided by DER that do not include BTM solar
- New energy market designs
- Services targeted primarily to end customers instead of the electric system's operators
- Regulatory rate cases or tariff designs

3. Topic Area 5.3: Advanced PV Controls and Cybersecurity

Projects seeking to develop partnerships and best practices to tackle cybersecurity challenges should refer to Topic Area 3.1: Collaborative Partnerships to Address Regulatory Burdens.

This topic will support research, development, and demonstration of technology solutions that enhance the visibility and control of PV inverters and sensors, while improving the security of those devices from cyberattack. SETO is interested in research in three interrelated areas:

- Innovative and scalable methods to integrate data measurements from PV inverters and sensors into utility information systems
- Advanced controls for grid-forming inverters to establish system frequency and voltage and thus enable collaborative operation for enhanced resilience

- Cybersecurity capabilities for solar technology, including encryption, signal integrity, authentication, firmware updates, and resilience over the lifetime of the assets

Applicants should consider the Department of Energy Office of Cybersecurity, Energy Security, and Emergency Response[79] multiyear plan goals when developing their proposed research projects.

Topic Area 5.3.a: Integration of Data from PV Inverters and Behind-the-Meter Sensors

The main objective of this topic is to develop and field-validate the integration of data from smart inverters and other BTM resources into utility information systems to enhance distribution grid visibility and operational situational awareness. Despite the wide adoption of smart meters, micro-synchrophasors, and other sensing technologies, measurements for BTM loads and generation are not integrated into grid management tools. This lack of BTM situational awareness has caused grid operation challenges even in existing applications, such as load forecasting. These projects will work to integrate data from BTM sensors to enhance the visibility and enable control of distributed solar energy resources, facilitate system restoration efforts, and improve distribution system resiliency.

Projects should include individual and/or aggregation of sensor data and other information as direct measurements, data cloud systems, or non-utility-owned data. Use of existing sensors and measurement data is preferred. Projects should work to integrate this data into utility information technology and operational technology systems in a dynamic, synchronized manner to enhance the situational awareness of utility real-time operating systems. Those systems could include SCADA systems, energy and distribution management systems, advanced metering infrastructure, distributed energy resource management systems, forecasting tools, or inverter measurements.

Applications should employ seamless integration of measurements into distribution system operations while supporting utility tools for situational awareness and diagnostics. Applications should address situational awareness that improves resiliency under normal, steady-state conditions and during abnormal events, and provides accurate calculation of real-time BTM solar generation. The applications should also address the interoperability of PV data and other proposed BTM sensors

[79] U.S. Department of Energy Office of Electricity Delivery & Energy Reliability. *Multiyear Plan for Energy Sector Cybersecurity*. https://www.energy.gov/sites/prod/files/2018/05/f51/DOE%20Multiyear%20Plan%20for%20Energy%20Sector%20Cybersecurity%20_0.pdf. March 2018.

within utility systems. The integration of this data should align with utility geo-referenced data.

Applicants should prioritize effort and funding toward sensor and data gathering and processing, including edge-based analytics, and integration into utility operational technologies systems. Successful applications should also seek to advance situational awareness, power system model validation, and control software applications development. As this is a new area of research and development, new metrics are needed to evaluate the performance of the technologies being developed. Applicants are encouraged to develop capabilities such as those in the table below and to establish their own ambitious performance metrics for these capabilities, such as:

Capability	Example Performance Metric
Sensor utilization (number of inverters, sensors)	Utilizes hundreds of sensors
Scalability	Visibility into 1 million nodes
Database	Synchronization of data among information and operations technologies databases
Interoperability, hierarchical data sharing	International Electrotechnical Commission (IEC) 61850 or equivalent for devices, IEC 61968 or equivalent for utility enterprise; hierarchical data aggregation and sharing, especially for transmission and distribution interfaces
Computation cycle	Fast enough to support operational planning (steady-state) to real-time operations (dynamic)
Communications availability, and latency	Supports real-time, robust sample frequency design
Redundancy	Adequate redundancy to ensure performance of system capability, anticipating normal data and other interruptions
Privacy	Supports customer confidentiality; follow PII and Critical Energy/Electric Infrastructure requirements
Integration	Integrates with existing utility information technology and operational technology systems and extendable for future applications
Security	Secure Application Programming Interface required
Data resilience	Data availability during abnormal events
Geographic Identification	Provides geographic information of sensors for interoperability
Verification and metadata	Data calibration and integration across systems, data verification, anomaly detection, and time stamps required
Situational awareness and utility support diagnostics	Reliably detect multiple network topology changes for real-time operations
Economical	Provides cost-benefit for all stakeholders

Applications Specifically Not of Interest

- Applications that do not include PV plant data, especially converter or inverter data
- Applications to deploy existing sensors, measurement, and communications systems that lack significant innovation in the integration and synchronization of PV inverter-based measurements and BTM data into utility situational awareness
- Applications to implement existing protocols and standards that lack significant innovation
- Applications that focus on standards development
- Applications that focus on solar and/or load forecasting algorithms and tools
- Applications with a primary focus on cybersecurity—these will be considered under Topic 5.3.c

Topic Area 5.3.b: Advanced Controls for Grid-forming Inverters

The main objective of this topic is to develop and field-validate next-generation grid-forming smart PV inverters that can collectively establish frequency, maintain voltage magnitude, provide stability, and enable black start in a distribution feeder with high penetration of PV. Grid-forming inverters[80] have the capability to regulate voltage magnitude and frequency in a power system similar to conventional generators. Traditionally, the grid-forming function is performed by central generators. When there is an outage, distribution feeders with DER with minimal or no synchronous generation could potentially serve the critical loads, thereby providing local resilience. This presents the opportunity for grid-forming functionality in PV inverters. While steady-state behavior of such resilient systems is well understood, more research is needed to enable a grid-forming inverter to serve in a more dynamic situation. Further, controls must be autonomous without the need for significant communication between different generators. In addition to enabling resilient distribution feeders, grid-forming functions will also be more important in islanded grids and microgrids dominated by renewable energy generation.

This topic seeks to advance grid-forming inverter controls to include functionality like coordinated control between grid-forming and grid-feeding inverters, islanded operation, dynamic operation, stability margins, coordination with other generation, such as wind, scalability, and more. Projects should focus on the controls of multiple grid-forming PV inverters to improve stability and resiliency of the electric system.

[80] *IEEE Power and Energy Magazine*. "Achieving a 100% Renewable Grid: Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy." https://ieeexplore.ieee.org/document/7866938. March–April 2017.

Applications of interest include but are not limited to:

- Modeling, control, coordination, and field validation of grid-forming PV inverters at scale in microgrids, software, and control applications that can be applied to a new generation of hardware-enhanced modular PV inverters for better coordination among such inverters
- Remedial actions and grid-forming controls to prevent blackouts by islanding and distribution service restoration
- Distributed stability controls integrated with grid-forming PV inverters that will take into account inherent stability issues like transient over-voltages, voltage oscillations, and frequency oscillations in weak grids
- Control tactics for 100% inverter-based generation in resilient microgrids
- Studies on performance of grid-forming PV inverters under grid fault scenarios and other related challenges in grid forming controls

Proposed grid-forming inverter controls should meet the following metrics:

- They should coordinate with more than 20 PV inverters at different power levels that have a varying mix of grid-following and grid-forming functions with DER instantaneous penetration of 90% or higher. DER can include solar, wind generators, and energy storage.
- The controls should provide fast frequency response and frequency variations within ±0.5 hertz under load variations ranging from 10% to 100% of full load at different time scales.
- Black-start functionality should be able to perform without help from rotating generators.
- Scalability must be proved theoretically and verified using simulation for different aspects that include more than 100 inverters and more than 1,000 nodes.

The project team must define further metrics on stability, reliability, and resiliency of the demonstration system with grid-forming inverters. Demonstrations of particular interest include large-scale testing with multiple grid-forming inverters, DER, and dynamic loads with a combined power rating of more than 100 kilowatts that will use real hardware and controls, demonstrated either in a controlled environment or in a field.

Applications Specifically Not of Interest

- Inverter hardware development, such as power converter topologies and wide-bandgap device designs, incorporation of additional sensors within inverter/converter designs, and magnetics and filter design

Topic Area 5.3.c: Photovoltaic Systems Cybersecurity

The main objective of this topic is to develop and field-validate enhanced cybersecurity capabilities for solar PV equipment, such as PV inverters and converters, to improve cybersecurity over the lifetime of the assets. PV systems often use communications tools to transmit data to grid operators and others, and this provides opportunities for cyberattack. In addition, as grid support services from PV systems increase, so does the capability for those systems to enable grid disturbances. Applicants should review the Sandia National Laboratories report *Roadmap for Photovoltaic Cyber Security.*[81]

This topic seeks to address several challenges that PV systems pose to cybersecurity, such as the required telecommunications infrastructure, volume of data, interoperability latency, robustness of the proposed solutions during disturbances and outages, and telecommunications failures. These projects should use novel approaches that include supply chain management, encryption, signal integrity, authentication, firmware updates, or technologies to boost PV resilience to cyberattacks. Applications should address strengthening the cybersecurity prevention, detection, or mitigation capabilities at the point of coupling.

Applicants may define their own performance metrics but should include the following:

- Applicable standards for DER devices and servers, such as UL Std. 2900-2-4
- Physical and logical DER boundaries and requirements for data in flight
- DER control network topology requirements and interface rules for secure network architecture
- Protection mechanisms, data types, associated ownership, and permissions for BTM access controls
- Patching and maintenance guidelines for BTM DER
- The recommended auditing practices for DER utility networks and aggregations

Projects of interest include but are not limited to:

- Identification of vulnerabilities in the inverter hardware, software, and firmware
- Enabling avoidance of malicious attacks to individual units at the local level and their propagation to centralized or distributed information systems
- Enhancements to smart inverter and distributed solar system hardware, firmware, or software or the distributed generation supply chain
- Designs of mitigation of cybersecurity issues around technologies related to local reliability and resilience

[81] Sandia National Laboratories. *Roadmap for Photovoltaic Cyber Security.* https://www.researchgate.net/publication/322568290_Roadmap_for_Photovoltaic_Cyber_Security. December 2017.

- Standardization of cybersecurity interoperability for information technology and operational technology systems
- Design of mitigation of cybersecurity issues around technologies like blockchain

Projects seeking to develop strategic changes among organizations to address cybersecurity concerns raised by the growing number of internet-connected distributed energy resources should refer to Topic 3.1 of this FOA.

All work under EERE funding agreements must be performed in the United States. See Section IV.L.iii. and Appendix C.

C. Applications Specifically Not of Interest

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

- Applications that fall outside the technical parameters specified in Section I.A. and I.B. of the FOA
- Applications for proposed technologies that are not based on sound scientific principles, such as anything that violates the laws of thermodynamics
- Other topic areas designated specifically not of interest can be found within each Topic Area description in Section I.B., above.

D. Authorizing Statutes

The programmatic authorizing statute is EPACT 2005, Section 931 (a)(2)(A). Awards made under this announcement will fall under the purview of 2 Code of Federal Regulation (CFR) Part 200 as amended by 2 CFR Part 910.

II. Award Information

A. Award Overview

i. Estimated Funding

EERE expects to make a total of approximately $130 million of federal funding available for new awards under this FOA, subject to the availability of appropriated funds. EERE anticipates making approximately 55 to 84 awards under this FOA. EERE may issue one, multiple, or no awards. Individual awards may vary between $200,000 and $5 million.

EERE may issue awards in one, multiple, or none of the following topic areas:

Topic Title		Details (topic funding and award numbers are approximate)
Topic 1: Photovoltaics Research and Development (20% to 50% cost share, technology readiness level[82] (TRL) 2 to 6)		
1.1.	Multi-Year Photovoltaics Applied Research Collaborations	$24 million total $5 million maximum per award Up to 3 years with an option to apply for an additional 2 years 3 to 6 awards
1.2.	Small Innovative Projects in Solar (SIPS)	$2 million total $200,000 maximum per award Up to 1 year 9 to 12 awards
Topic 2: CSP Research and Development (20% to 50% cost share, TRL 2 to 6)		
2.1	Firm Thermal Energy Storage	$11 million total $8 million maximum per award Up to 3 years 2 to 6 awards
2.2	Materials and Manufacturing for CSP	$11 million total $5 million maximum per award Up to 3 years 3 to 6 awards
2.3	Autonomous Solar Collector Fields	$11 million total $8 million maximum per award Up to 3 years 2 to 6 awards
Topic 3: Balance of System Soft Costs Reduction (20% cost share, TRL 2 to 5)		
3.1	Collaborative Partnerships to Address Regulatory Burdens	$8 million total $1.5 million maximum per award Up to 3 years 5 to 8 awards
3.2	Data and Methodologies to Assess Avian Impacts	$4 million total $2 million maximum per award Up to 3 years 2 to 3 awards

[82] See Appendix F for a description of technology readiness levels.

3.3	Increasing Solar Affordability through Innovative Solar Finance	$3 million total $1.5 million maximum per award Up to 3 years 2 to 3 awards
3.4	Rapid Solar Software Development	$2 million total $350,000 maximum per award Up to 1 year 6 to 7 awards
Topic 4: Innovations in Manufacturing – Hardware Incubator (20% to 50% cost share, TRL 2 to 6)		
4	Innovations in Manufacturing – Hardware Incubator	$10 million total $1 million maximum per award Up to 1.5 years (18 months) 10 to 12 awards
Topic 5: Advanced Solar Systems Integration Technologies (20% to 50% cost share, TRL 2 to 6)		
5.1	Adaptive Distribution Protection	$14 million total $5 million maximum per award Up to 3 years 3 to 4 awards
5.2	Grid Services from Behind-the-Meter (BTM) Solar and other DERs	$12 million total $3 million maximum per award Up to 3 years 4 to 5 awards
5.3	Advanced PV Controls and Cybersecurity	$18 million total $5 million maximum per award Up to 3 years 4 to 6 awards

EERE may establish more than one budget period for each award and fund only the initial budget period(s). Funding for all budget periods, including the initial budget period, is not guaranteed. Before the expiration of the initial budget period(s), Topic Area 1.1 recipients will be subject to a competitive down-select process, and SETO will provide additional funding only to a subset of recipients. More information on the down-select process is provided in Section VI.C.

i. Period of Performance

EERE anticipates making awards that will run up to 60 months in length, comprised of one or more budget periods. Project continuation will be contingent upon satisfactory performance and Go/No-Go decision review. At the Go/No-Go decision points, EERE will evaluate project performance, project schedule adherence, meeting milestone objectives, compliance with reporting requirements, and overall contribution to the program goals and objectives. As a result of this evaluation, EERE will make a determination to continue to fund the

project, recommend re-direction of work under the project, place a hold on federal funding for the project, or discontinue funding the project.

ii. New Applications Only

EERE will accept only new applications under this FOA. EERE will not consider applications for renewals of existing EERE-funded awards through this FOA.

B. EERE Funding Agreements

Through Cooperative Agreements and other similar agreements, EERE provides financial and other support to projects that have the potential to realize the FOA objectives. EERE does not use such agreements to acquire property or services for the direct benefit or use of the United States Government.

i. Cooperative Agreements

EERE generally uses Cooperative Agreements to provide financial and other support to prime recipients.

Through Cooperative Agreements, EERE provides 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.

EERE has substantial involvement in all projects funded via Cooperative Agreement. See Section VI.B.ix. of the FOA for more information on what substantial involvement may involve.

ii. Funding Agreements with Federally Funded Research and Development Center (FFRDCs)

In most cases, FFRDCs are funded independently of the remainder of the Project Team. The FFRDC then executes an agreement with any non-FFRDC Project Team members to arrange work structure, project execution, and any other matters. Regardless of these arrangements, the entity that applied as the prime recipient for the project will remain the prime recipient for the project.

iii. Grants

Although EERE has the authority to provide financial support to prime recipients through Grants, EERE generally does not fund projects through Grants. EERE may fund a limited number of projects through Grants, as appropriate.

iv. Technology Investment Agreements (TIAs)

In rare cases and if determined appropriate, EERE will consider awarding a TIA to a non-FFRDC applicant. TIAs, governed by 10 CFR Part 603, are assistance instruments used to increase the involvement of commercial entities in the Department's research, development, and demonstration programs. A TIA may be either a type of cooperative agreement or an assistance transaction other than a cooperative agreement, depending on the intellectual property provisions. In both cases, TIAs are not necessarily subject to all of the requirements of 2 CFR Part 200 as amended by 2 CFR Part 910.

In a TIA, EERE may modify the standard Government terms and conditions, including but not limited to:

- Intellectual Property Provisions: EERE may negotiate special arrangements with recipients to avoid the encumbrance of existing intellectual property rights or to facilitate the commercial deployment of inventions conceived or first actually reduced to practice under the EERE funding agreement.
- Accounting Provisions: EERE may authorize the use of Generally Accepted Accounting Principles (GAAP) where recipients do not have accounting systems that comply with Government recordkeeping and reporting requirements.

EERE will be more amenable to awarding a TIA in support of an application from a consortium or a team arrangement that includes cost sharing with the private sector, as opposed to an application from a single organization. Such a consortium or teaming arrangement could include a FFRDC. If a DOE/NNSA FFRDC is a part of the consortium or teaming arrangement, the value of, and funding for the DOE/NNSA FFRDC portion of the work will be authorized and funded under the DOE field work authorization system and performed under the laboratory's Management and Operating contract. Funding for a non-DOE/NNSA FFRDC would be through an interagency agreement under the Economy Act or other statutory authority. Other appropriate contractual accommodations, such as those involving intellectual property, may be made through a "funds in" agreement to facilitate the FFRDCs' participation in the consortium or teaming arrangement. If a TIA is awarded, certain types of information described in 10 CFR 603.420(b) are exempt from disclosure under the Freedom of Information Act (FOIA) for five years after DOE receives the information.

An applicant may request a TIA if it believes that using a TIA could benefit the RD&D objectives of the program (see Section 603.225) and can document these benefits. If an applicant is seeking to negotiate a TIA, the applicant must include an explicit request in its Full Application. After an applicant is selected for award

negotiation, the Contracting Officer will determine if awarding a TIA would benefit the RD&D objectives of the program in ways that likely would not happen if another type of assistance agreement (e.g., cooperative agreement subject to the requirements of 2 CFR Part 200 as amended by 2 CFR Part 910). The Contracting Officer will use the criteria in 10 CFR 603, Subpart B, to make this determination.

III. Eligibility Information

To be considered for substantive evaluation, an applicant's submission must meet the criteria set forth below. If the application does not meet these eligibility requirements, it will be considered ineligible and removed from further evaluation.

The eligibility requirements under Section III.A. of this section apply to all applicants of this FOA, except:

Topic 1 Eligibility Restriction: DOE and National Nuclear Security Agency (NNSA) Federally Funded Research and Development Centers (FFRDC) and national laboratories are not eligible to apply as prime recipients and may be included only as subrecipients on applications for Topic 1: Photovoltaics Research and Development. The scope of work performed by the prime recipient shall not be less than the scope of work performed by the subrecipients who are ineligible to be prime applicants, as measured by the total project costs.

Topic 4 Eligibility Restriction: Eligibility is restricted to for-profit entities as the prime recipient of awards under Topic Area 4: Innovations in Manufacturing. Eligibility is restricted under Topic Area 4, because SETO believes that for-profit entities are the most likely entities to achieve the objectives required under this topic area, as they are the only entities with the capacity to rapidly commercialize new technologies related to innovations in manufacturing. The scope of work performed by the prime recipient shall not be less than the scope of work performed by the subrecipients who are ineligible to be prime applicants, as measured by the total project costs.

A. Eligible Applicants

v. Individuals

U.S. citizens and lawful permanent residents are eligible to apply for funding as a prime recipient or subrecipient.

vi. Domestic Entities

For-profit entities, educational institutions, and nonprofits that are incorporated (or otherwise formed) under the laws of a particular State or territory of the United

States and have a physical location for business operations in the United States are eligible to apply for funding as a prime recipient or subrecipient. 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.

State, local, and tribal government entities are eligible to apply for funding as a prime recipient or subrecipient.

DOE/NNSA FFRDCs are eligible to apply for funding as a prime recipient or subrecipient, except under Topic 1 and Topic 4, where they cannot apply as prime, as described above.

Non-DOE/NNSA FFRDCs are eligible to apply for funding as a subrecipient, but are not eligible to apply as a prime recipient.

Federal agencies and instrumentalities (other than DOE) are eligible to apply for funding as a subrecipient, but are not eligible to apply as a prime recipient.

vii. Foreign Entities

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding under this FOA. Other than as provided in the "Individuals" or "Domestic Entities" sections above, all prime recipients receiving funding under this FOA must be incorporated (or otherwise formed) under the laws of a State or territory of the United States and have a physical location for business operations in the United States. If a foreign entity applies for funding as a prime recipient, it must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed) under the laws of a State or territory of the United States to be the prime recipient. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate.

Foreign entities may request a waiver of the requirement to designate a subsidiary in the United States as the prime recipient in the Full Application (i.e., a foreign entity may request that it remains the prime recipient on an award). To do so, the applicant must submit an explicit written waiver request in the Full Application. Appendix C lists the necessary information that must be included in a request to waive this requirement. The applicant does not have the right to appeal EERE's decision concerning a waiver request.

In the waiver request, the applicant must demonstrate to the satisfaction of EERE that it would further the purposes of this FOA and is otherwise in the economic interests of the United States to have a foreign entity serve as the prime recipient. EERE may require additional information before considering the waiver request.

A foreign entity may receive funding as a subrecipient.

viii. Incorporated Consortia

Incorporated consortia, which may include domestic and/or foreign entities, are eligible to apply for funding as a prime recipient or subrecipient. For consortia incorporated (or otherwise formed) under the laws of a State or territory of the United States, please refer to "Domestic Entities," above. For consortia incorporated in foreign countries, please refer to the requirements in "Foreign Entities," above.

Each incorporated consortium must have an internal governance structure and a written set of internal rules. Upon request, the consortium must provide a written description of its internal governance structure and its internal rules to the EERE Contracting Officer.

ix. Unincorporated Consortia

Unincorporated Consortia, which may include domestic and foreign entities, must designate one member of the consortium to serve as the prime recipient/consortium representative. The prime recipient/consortium representative must be incorporated (or otherwise formed) under the laws of a State or territory of the United States. The eligibility of the consortium will be determined by the eligibility of the prime recipient/consortium representative under Section III.A. of the FOA.

Upon request, unincorporated consortia must provide the EERE 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
- Provisions for ownership and rights in intellectual property developed previously or under the agreement

B. Cost Sharing

The cost share must be at least 20% of the total allowable costs (i.e., the sum of the government share, including FFRDC costs if applicable, and the recipient share of allowable costs equals the total allowable cost of the project) for R&D projects and 50% of the total allowable costs for demonstration and commercial application projects and

must come from non-federal sources unless otherwise allowed by law. (See 2 CFR 200.306 and 2 CFR 910.130 for the applicable cost sharing requirements.)

The following table illustrates the anticipated focus and required cost share for projects' demonstration activities, along with the anticipated time frames for each phase. Demonstration is an option for all projects in Topics 1, 2, 4, and 5 but may not be possible or applicable, depending on the technology, technology readiness level,[83] or current regulations and market structures. Any proposed project with demonstration is required to provide at least 50% cost share during the validation period.

	Budget Period 1	Budget Period 2	Budget Period 3
R&D projects *without* demonstration	Research and development (20% cost share)		
R&D projects *with* demonstration In Budget Period 3	Research and development (20% cost share)		Demonstration (50% cost share)

PLEASE NOTE: Section 108, "Short-Term Cost-Share Pilot Program" of the Department of Energy Research and Innovation Act (RIA), Pub. L. 115-246, amended EPACT 2005 section 988 to include a 2-year pilot program exempting institutions of Higher Education and Non-Profit Organizations from the minimum 20 percent cost share requirement for research and development activities. Nevertheless, RIA did not change the cost share requirements set forth in 2 CFR 910.130 of DOE's financial assistance regulation and the requirements of that regulation remain in effect. Until the regulation is amended to align with RIA or a cost share reduction or elimination is issued, DOE programs and Contracting Officers must adhere to the cost share requirements as set forth in 2 CFR 910.130. Independent of the EPACT 2005 section 988 and 2 CFR 910.130 requirements and the Pilot Program notwithstanding, DOE may require cost share of any activity as a matter of programmatic discretion.

To assist applicants in calculating proper cost share amounts, EERE has included a cost share information sheet and sample cost share calculation as Appendices A and B to this FOA.

i. Legal Responsibility

Although the cost share requirement applies to the project as a whole, including work performed by members of the project team other than the prime recipient, the prime recipient is legally responsible for paying the entire cost share. If the funding agreement is terminated prior to the end of the project period, the

[83] See Appendix F for further discussion of technology readiness levels.

prime recipient is required to contribute at least the cost share percentage of total expenditures incurred through the date of termination.

The prime recipient is solely responsible for managing cost share contributions by the project team and enforcing cost share obligation assumed by project team members in subawards or related agreements.

ii. Cost Share Allocation

Each project team is free to determine how best to allocate the cost share requirement among the team members. 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.

iii. Cost Share Types and Allowability

Every cost share contribution must be allowable under the applicable federal cost principles, as described in Section IV.L.i. of the FOA. In addition, cost share must be verifiable upon submission of the Full Application.

Project teams may provide cost share in the form of cash or in-kind contributions. Cost share may be provided by the prime recipient, subrecipients, or third parties (entities that do not have a role in performing the scope of work). Vendors/contractors may not provide cost share. Any partial donation of goods or services is considered a discount and is not allowable.

Cash contributions include, but are not limited to: personnel costs, fringe costs, supply and equipment costs, indirect costs and other direct costs.

In-kind contributions are those where a value of the contribution can be readily determined, verified and justified but where no actual cash is transacted in securing the good or service comprising the contribution. Allowable in-kind contributions include but are not limited to the donation of space or use of equipment.

Project teams may use funding or property received from state or local governments to meet the cost share requirement, so long as the funding 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 including, but not limited to:

- 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)
- Expenditures that were reimbursed under a separate federal program

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. As all sources of cost share are considered part of total project cost, the cost share dollars will be scrutinized under the same federal regulations as federal dollars to 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 are encouraged to refer to 2 CFR 200.306 as amended by 2 CFR 910.130 for additional guidance on cost sharing.

iv. Cost Share Contributions by FFRDCs

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

v. Cost Share Verification

Applicants are required to provide written assurance of their proposed cost share contributions in their Full Applications.

Upon selection for award negotiations, applicants are required to provide additional information and documentation regarding their cost share contributions. Please refer to Appendix A of the FOA.

vi. Cost Share Payment

EERE requires prime recipients to contribute the cost share amount incrementally over the life of the award. Specifically, the prime recipient's cost share for each billing period must always reflect the overall cost share ratio negotiated by the parties. An example of this is the total amount of cost sharing on each invoice when considered cumulatively with previous invoices must reflect, at a minimum, the cost sharing percentage negotiated. As FFRDC funding will be provided directly to the FFRDC(s) by DOE, prime recipients will be required to provide project cost share at a percentage commensurate with the

FFRDC costs, on a budget period basis, resulting in a higher interim invoicing cost share ratio than the total award ratio.

In limited circumstances, and where it is in the government's interest, the EERE Contracting Officer may approve a request by the prime recipient to meet its cost share requirements on a less frequent basis, such as monthly or quarterly. Regardless of the interval requested, the prime recipient must be up-to-date on cost share at each interval. Such requests must be sent to the Contracting Officer during award negotiations and include the following information: (1) a detailed justification for the request; (2) a proposed schedule of payments, including amounts and dates; (3) a written commitment to meet that schedule; and (4) such evidence as necessary to demonstrate that the prime recipient has complied with its cost share obligations to date. The Contracting Officer must approve all such requests before they go into effect.

C. Compliance Criteria

LOI, Concept Papers, Full Applications, and Replies to Reviewer Comments must meet all compliance criteria listed below or they will be considered noncompliant. EERE will not review or consider noncompliant submissions, including LOI, Concept Papers, Full Applications, and Replies to Reviewer Comments that were: submitted through means other than EERE Exchange; submitted after the applicable deadline; and/or submitted incomplete. EERE will not extend the submission deadline for applicants who fail to submit required information due to server/connection congestion.

i. Compliance Criteria

1. *Letters of Intent*

LOI are deemed compliant if:

The applicant entered all required information and clicked the "Create Submission" button in EERE Exchange by the deadline stated in the FOA.

2. *Concept Papers*

Concept Papers are deemed compliant if:

- The applicant submitted a compliant LOI;
- The Concept Paper complies with the content and form requirements in Section IV.D. of the FOA; and
- The applicant successfully uploaded all required documents and clicked the "Submit" button in EERE Exchange by the deadline stated in this FOA.
- For Topic Area 1.2 SIPS, Concept Papers are not required. However, in order to clear an administrative software restriction of EERE Exchange,

for the Concept Paper stage, applicants **must resubmit their LOI before the Concept Paper deadline and submit a summary slide in order to be eligible to submit a SIPS application for review.**

3. *Full Applications*
   Full Applications are deemed compliant if:
   - The applicant submitted a compliant LOI and compliant Concept Paper;
   - The Full Application complies with the content and form requirements in Section IV.F. of the FOA; and
   - The applicant successfully uploaded all required documents and clicked the "Submit" button in EERE Exchange by the deadline stated in the FOA.

4. *Replies to Reviewer Comments*
   Replies to Reviewer Comments are deemed compliant if:
   - The Reply to Reviewer Comments complies with the content and form requirements in Section IV.G. of the FOA; and
   - The applicant successfully uploaded all required documents to EERE Exchange by the deadline stated in the FOA.

D. Responsiveness Criteria

All "Applications Specifically Not of Interest," as described in Section I.C. of the FOA, are deemed nonresponsive and are not reviewed or considered.

E. Other Eligibility Requirements

i. Requirements for DOE/National Nuclear Security Agency (NNSA) Federally Funded Research and Development Centers (FFRDC) Listed as the applicant

A DOE/NNSA FFRDC is eligible to apply for funding under this FOA, with the exception of Topic 1 and Topic 4, as described above, if its cognizant Contracting Officer provides written authorization and this authorization is submitted with the application.

The following wording is acceptable for the authorization:

> Authorization is granted for the Laboratory to participate in the proposed project. The work proposed for the laboratory is consistent with or complementary to the missions of the laboratory, and will not adversely impact execution of the DOE assigned programs at the laboratory.

(end of acceptable authorization)

If a DOE/NNSA FFRDC is selected for award negotiation, the proposed work will be authorized under the DOE work authorization process and performed under the laboratory's management and operating contract.

ii. Requirements for DOE/NNSA and non-DOE/NNSA Federally Funded Research and Development Centers Included as a Subrecipient

DOE/NNSA and non-DOE/NNSA FFRDCs may be proposed as a subrecipient on another entity's application subject to the following guidelines:

5. *Authorization for non-DOE/NNSA FFRDCs*
The federal agency sponsoring the FFRDC must authorize in writing the use of the FFRDC on the proposed project and this authorization must be submitted with the application. The use of a FFRDC must be consistent with its authority under its award.

6. *Authorization for DOE/NNSA FFRDCs*
The cognizant Contracting Officer for the FFRDC must authorize in writing the use of the FFRDC on the proposed project and this authorization must be submitted with the application. The following wording is acceptable for this authorization:

Authorization is granted for the laboratory to participate in the proposed project. The work proposed for the laboratory is consistent with or complementary to the missions of the laboratory, and will not adversely impact execution of the DOE assigned programs at the laboratory.

7. *Value/Funding*
The value of and funding for the FFRDC portion of the work will not normally be included in the award to a successful applicant. Usually, DOE will fund a DOE/NNSA FFRDC contractor through the DOE field work proposal system and non-DOE/NNSA FFRDC through an interagency agreement with the sponsoring agency.

8. *Cost Share*
Although the FFRDC portion of the work is usually excluded from the award to a successful applicant, the applicant's cost share requirement will be based on the total cost of the project, including the applicant's, the subrecipient's, and the FFRDC's portions of the project.

9. *Responsibility*
The prime recipient will be 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 the FFRDC contractor.

10. *Limit on FFRDC Effort*
See eligibility restriction for Topic 1 and Topic 4.

F. Limitation on Number of Concept Papers and Full Applications Eligible for Review

An entity may submit more than one LOI, Concept Paper, and Full Application to this FOA, provided that each application describes a unique, scientifically distinct project and provided that an eligible LOI and Concept Paper was submitted for each Full Application.

G. Questions Regarding Eligibility

EERE will not make eligibility determinations for potential applicants prior to the date on which applications to this FOA must be submitted. The decision whether to submit an application in response to this FOA lies solely with the applicant.

IV. Application and Submission Information

A. Application Process

The application process will include three phases: an LOI phase, Concept Paper phase, and a Full Application phase. **Only applicants who have submitted an LOI and an eligible Concept Paper will be eligible to submit a Full Application**. At each phase, EERE performs an initial eligibility review of the applicant submissions to determine whether they meet the eligibility requirements of Section III of the FOA. EERE will not review or consider submissions that do not meet the eligibility requirements of Section III. All submissions must conform to the following form and content requirements, including maximum page lengths (described below) and must be submitted via EERE Exchange at https://eere-exchange.energy.gov/, unless specifically stated otherwise. **EERE will not review or consider submissions submitted through means other than EERE Exchange, submissions submitted after the applicable deadline, or incomplete submissions**. EERE will not extend deadlines for applicants who fail to submit required information and documents due to server/connection congestion.

A **Control Number** will be issued when an applicant begins the EERE Exchange application process. This control number must be included with all application documents, as described below.

The Concept Paper, Full Application, and Reply to Reviewer Comments must conform to the following requirements:

- Each must be submitted in Adobe PDF format unless stated otherwise;
- Each must be written in English;
- All pages must be formatted to fit on 8.5 x 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 or tables, which may be 10-point font). A symbol font may be used to insert Greek letters or special characters, but the font size requirement still applies. References must be included as footnotes or endnotes in a font size of 10 or larger. Footnotes and endnotes are counted toward the maximum page requirement;
- 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; and
- Each submission must not exceed the specified maximum page limit, including cover page, charts, graphs, maps, and photographs when printed using the formatting requirements set forth above and single-spaced. If applicants exceed the maximum page lengths indicated below, EERE will review only the authorized number of pages and disregard any additional pages.

  Applicants are responsible for meeting each submission deadline. **Applicants are strongly encouraged to submit their LOI, Concept Papers and Full Applications at least 48 hours in advance of the submission deadline**. Under normal conditions (at least 48 hours in advance of the submission deadline), applicants should allow at least one hour to submit an LOI, Concept Paper, Full Application, or Reply to Reviewer Comments. Once the LOI, Concept Paper, Full Application, or Reply to Reviewer Comments is submitted in EERE Exchange, applicants may revise or update that submission until the expiration of the applicable deadline. If changes are made, the applicant must resubmit the LOI, Concept Paper, Full Application, or Reply to Reviewer Comments before the applicable deadline.

  EERE urges applicants to carefully review their LOI Concept Papers, and Full Applications and to allow sufficient time for the submission of required information and documents. All Full Applications that pass the initial eligibility review will undergo comprehensive technical merit review according to the criteria identified in Section V.A.ii. of the FOA.

i. Additional Information on EERE Exchange

EERE Exchange is designed to enforce the deadlines specified in this FOA. The "Apply" and "Submit" buttons will automatically disable at the defined submission deadlines. Should applicants experience problems with EERE Exchange, the following information may be helpful.

Applicants that experience issues with submission PRIOR to the FOA deadline: In the event that an applicant experiences technical difficulties with a submission, the applicant should contact the EERE Exchange helpdesk for assistance (EERE-ExchangeSupport@hq.doe.gov). The EERE Exchange helpdesk and/or the EERE Exchange system administrators will assist applicants in resolving issues.

Applicants that experience issues with submissions that result in late submissions: In the event that an applicant experiences technical difficulties so severe that they are unable to submit their application by the deadline, the applicant should contact the EERE Exchange helpdesk for assistance (EERE-ExchangeSupport@hq.doe.gov). The EERE Exchange helpdesk and/or the EERE Exchange system administrators will assist the applicant in resolving all issues (including finalizing submission on behalf of and with the applicant's concurrence). Please note, network traffic is at its heaviest during the final hours and minutes prior to submittal deadline. Applicants who experience this during the final hours or minutes and are unsuccessful in uploading documents will not be able to use this process.

B. Application Forms

The application forms and instructions are available on EERE Exchange. To access these materials, go to https://eere-Exchange.energy.gov and select the appropriate funding opportunity number.

Note: The maximum file size that can be uploaded to the EERE Exchange website is 10MB. Files in excess of 10MB cannot be uploaded, and hence cannot be submitted for review. If a file exceeds 10MB but is still within the maximum page limit specified in the FOA, it must be broken into parts and denoted to that effect. For example:
ControlNumber_LeadOrganization_Project_Part_1
ControlNumber_LeadOrganization_Project_Part_2

C. Content and Form of the Letter of Intent

To be eligible to submit a Concept Paper and Full Application, applicants must submit an LOI by the specified due date and time. LOI will be used by EERE to plan for the merit review process. The letters should not contain any proprietary or sensitive business information. The letters will not be used for down-selection purposes, and do not commit an applicant to submit an application.

EERE will not review or consider ineligible LOI (see Section III of the FOA).

Each applicant must provide the following information as part of the LOI:

- Project title;
- Lead organization;
- Organization type (business < 500 employees; business > 1,000 employees; business 500-1,000 employees; FFRDC; government-owned, government-operated; nonprofit; university);
- Whether the application has been previously submitted to EERE;
- Percent of effort contributed by the lead organization;
- The project team, including:
  - The principal investigator for the prime recipient;
  - Team members, such as subrecipients; and
  - Key participants, namely individuals who contribute in a substantive, measureable way to the execution of the proposed project;
- Technical topic area; and
- Abstract, which should be no longer than 200 words and should provide a truncated explanation of the proposed project.

D. Content and Form of the Concept Paper

To be eligible to submit a Full Application, applicants must submit a Concept Paper by the specified due date and time.

i. Concept Paper Content Requirements

EERE will not review or consider ineligible Concept Papers (see Section III of the FOA).

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

The Concept Paper must conform to the following content requirements:

Section	Page Limit	Description
Cover Page	1 page maximum	The cover page should include the project title, the specific FOA Topic Area being addressed (if applicable), both the technical and business points of contact, names of all team member organizations, and any statements regarding confidentiality.
Technical Description,	4 pages maximum	Applicants are required to describe succinctly: • The proposed technology, including its basic operating principles and how it is unique and innovative;

Impacts and Addendum		• 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 EERE funding would have on the proposed project. Addendum Applicants are required to describe succinctly the qualifications, experience, and capabilities of the proposed project team, including: • Whether the principal investigator 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 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 effort and/or clearly explain how it intends to obtain access to the necessary equipment and facilities. Applicants may provide graphs, charts, or other data to supplement their technology description.

EERE makes an independent assessment of each Concept Paper based on the criteria in Section V.A.i. of the FOA. EERE will encourage a subset of applicants to submit Full Applications. Other applicants will be discouraged from submitting a Full Application. An applicant who receives a "discouraged" notification may still submit a Full Application. EERE will review all eligible Full Applications. However, by discouraging the submission of a Full Application, EERE intends to convey its lack of programmatic interest in the proposed project in an effort to save the applicant the time and expense of preparing an application that is unlikely to be selected for award negotiations.

EERE may include general comments provided from reviewers on an applicant's Concept Paper in the encourage/discourage notification posted on EERE Exchange at the close of that phase.

E. Content and Form of the Application for Topic Area 1.2: Small Innovative Projects in Solar

Applicants must submit a SIPS application by the specified due date and time to be considered for funding under Topic 1.2 of this FOA.

ii. SIPS Application Content Requirements

Applicants to Topic Area 1.2: SIPS must submit a mandatory LOI. For the Concept Paper stage, applicants **must resubmit their LOI and submit a summary slide in order to be eligible to submit a SIPS application for review.** SIPS applications must be submitted by the SIPS Application deadline, which coincides with the Full Application deadline of other topics. All SIPS applicants should complete their submissions using the format provided in this section. Applicants will be unable to submit a SIPS application if they do not complete the above steps.

All SIPS Application documents must be marked with the Control Number issued to the applicant.

EERE will not review or consider non-compliant SIPS applications.

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

The SIPS application must conform to the following content requirements:

Section	Description

Cover Page [1 Page Max]	• Project Title
	• The specific FOA Topic Area being addressed and Project Focus Area(s): e.g., Photovoltaics, CdTe deposition, Reliability
	  • (Note: This will help sort applications and determine reviewer expertise areas needed for each application so careful consideration here is helpful.)
	• The Project Team and contact information, including:
	  • The Principal Investigator for the Prime Recipient (Technical Point of Contact).
	  • Team Members (i.e., Subrecipients); and
	  • Key Participants (i.e., individuals who contribute in a substantive, measureable way to the execution of the proposed project); and
	• Budget - Include a high-level overview of estimated total project budget
	• Any Statements regarding confidentiality
	• No additional information, such as an application abstract, should be included on this page

Project Description [3 Pages Max]	Applicants are required to describe succinctly: • The proposed technology or solution, including its basic operating principles and how it is unique and innovative; • The current state of the art in the relevant field and application, including key shortcomings, limitations, and challenges; • How the proposed project will overcome the shortcomings, limitations, and challenges in the relevant field and application; • The potential impact, with justification, that the proposed project would have on the relevant field and application and its relevance to industry and SETO goals as described in Section I.B. • Include a clear and concise (high-level) statement of the midpoint and end goals of the project. Each goal should be quantifiable and verifiable. • The most challenging risks the proposed project will likely face and mitigation strategies • The aspects of the team that are most relevant to the proposed work (i.e. applicant experience in the field and in working together, equipment and facilities access, etc.) • Applicants may provide graphs, charts, or other data to supplement their Technology Description, however, this supplemental information will count toward the page limit. In addition, an unlimited number of reference pages, one page letters of support and/or 1 page resumes of project participants may be submitted but are not required.

Summary Slide [Not included in page limit]	There is a PPT file template that can be downloaded from EERE Exchange. 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 and should be legible when viewed on a screen in a conference room. The Summary Slide requires the following information: • The project's key idea/takeaway • A description of the project's impact • Proposed project goals • Any key graphics (illustrations, charts, and/or tables) • Project title, Prime Recipient, Principal Investigator, and Subrecipients • Requested SETO funds and proposed applicant cost share (if applicable)

EERE makes an independent assessment of each SIPS application based on the criteria in Section V.A.ii. of the FOA.

F. Content and Form of the Full Application

Applicants must submit a Full Application by the specified due date and time to be considered for funding under this FOA. Applicants must complete the following application forms found on the EERE Exchange website at https://eere-Exchange.energy.gov/, in accordance with the instructions.

Applicants will have approximately 30 days from receipt of the Concept Paper Encourage/Discourage notification on EERE Exchange to prepare and submit a Full Application. Regardless of the date the applicant receives the Encourage/Discourage notification, the submission deadline for the Full Application remains the date and time stated on the FOA cover page.

All Full Application documents must be marked with the Control Number issued to the applicant. Applicants will receive a control number upon submission of their LOI, and should include that control number in the file name of their Full Application submission (i.e., *Control number_Applicant Name_Full Application*).

i. Full Application Content Requirements

EERE will not review or consider ineligible Full Applications (see Section III of the FOA).

Each Full Application shall be limited to a single concept or technology. Unrelated concepts and technologies shall not be consolidated in a single Full Application. Full Applications must conform to the following requirements:

Submission	Components	File Name
Full Application (PDF, unless stated otherwise)	Technical Volume (PDF format. See Chart in Section IV.D.ii.) 15-page limit	ControlNumber_LeadOrganization_TechnicalVolume
	SF-424 Application for Federal Assistance (PDF format)	ControlNumber_LeadOrganization_App424
	Budget Justification (Microsoft Excel format. Applicants must use the template available in EERE Exchange)	ControlNumber_LeadOrganization_Budget_Justification
	Summary for Public Release (PDF format. 1 page limit)	ControlNumber_LeadOrganization_Summary
	Summary Slide (Microsoft PowerPoint format. 1 page limit)	ControlNumber_LeadOrganization_Slide
	Subrecipient Budget Justification, if applicable (Microsoft Excel format. Applicants must use the template available in EERE Exchange)	ControlNumber_LeadOrganization_Subrecipient_Budget_Justification
	DOE WP for FFRDC, if applicable (PDF format. See DOE O 412.1A, Attachment 3)	ControlNumber_LeadOrganization_WP
	Authorization from cognizant Contracting Officer for FFRDC, if applicable (PDF format)	ControlNumber_LeadOrganization_FFRDCAuth
	SF-LLL Disclosure of Lobbying Activities (PDF format)	ControlNumber_LeadOrganization_SF-LLL
	Foreign Entity and Performance of Work in the United States waiver requests, if applicable (PDF format)	ControlNumber_LeadOrganization_Waiver
	U.S. Manufacturing Plan (PDF format) (except for Topic 1.2 and Topic 3)	ControlNumber_LeadOrganization_USMP

Note: The maximum file size that can be uploaded to the EERE Exchange website is 10MB. Files in excess of 10MB cannot be uploaded, and hence cannot be submitted for review. If a file exceeds 10MB but is still within the maximum page limit specified in the FOA it must be broken into parts and denoted to that effect. For example:

ControlNumber_LeadOrganization_TechnicalVolume_Part_1
ControlNumber_LeadOrganization_TechnicalVolume_Part_2

EERE will not accept late submissions that resulted from technical difficulties due to uploading files that exceed 10MB.

EERE provides detailed guidance on the content and form of each component below.

ii. Technical Volume

The Technical Volume must be submitted in Adobe PDF format. 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, EERE will review only the authorized number of pages and disregard any additional pages. This volume must address the Merit Review Criteria as discussed in Section V.A.ii. of the FOA. Save the Technical Volume in a single PDF file using the following convention for the title: "ControlNumber_LeadOrganization_TechnicalVolume."

Applicants must provide sufficient citations and references to the primary research literature to justify the claims and approaches made in the Technical Volume. However, EERE and reviewers are under no obligation to review cited sources.

The Technical Volume to the Full Application may not be more than 15 pages, including the cover page, table of contents, and all citations, charts, graphs, maps, photos, or other graphics, and must include all of the information in the table below. The applicant should consider the weighting of each of the evaluation criteria (see Section V.A.ii. of the FOA) when preparing the Technical Volume.

The Technical Volume should clearly describe and expand upon information provided in the Concept Paper. The Technical Volume must conform to the following content requirements:

SECTION/PAGE LIMIT	DESCRIPTION
Cover Page	• Project Title • The specific FOA Topic Area being addressed and Project Focus Area(s): e.g., Photovoltaics, CdTe deposition, Reliability • (Note: This will help sort applications and determine reviewer expertise areas needed for each application so careful consideration here is helpful.) • The Project Team and contact information, including: • The Principal Investigator for the Prime Recipient (Technical Point of Contact). • Team Members (i.e., Subrecipients); and • Key Participants (i.e., individuals who contribute in a substantive, measureable way to the execution of the proposed project); and • Any statements regarding confidentiality • No additional information, such as an application abstract, should be included on this page

Project Overview	The Project Overview should contain the following information: • Background: The applicant should discuss the background of their organization, including the history, successes, and current research and development status (i.e., the technical baseline) relevant to the technical topic being addressed in the full application. • Project Objectives/Goals: The applicant should provide a clear and concise (high-level) statement of the goals and objectives of the project as well as the expected outcomes. The applicant should explicitly identify the targeted improvements to the baseline technology and the critical success factors in achieving that goal. • Relevant, previous work efforts, demonstrated innovations, and how these enable the applicant to achieve the project objectives. • DOE Impact: The applicant should discuss the impact that DOE funding would have on the proposed project. Applicants should specifically explain how DOE funding, relative to prior, current, or anticipated funding from other public and private sources, is necessary to achieve the project objectives.
Project Description, Innovation, and Impact	The Project Description should contain the following information: • Relevance and Outcomes: The applicant should provide a detailed description of the project for the first and final years, including the activities, objectives, and outcomes that will be pursued during the project. This section should describe the relevance of the proposed project to the goals and objectives of the FOA, including the potential to meet specific DOE mission targets or other relevant performance targets. • Feasibility: The applicant should demonstrate the feasibility of the proposed project and capability of achieving the anticipated performance targets for the first and final years, including a description of previous work done and prior results. • Innovation and Impact: The applicant should describe the current state of the applicable field, the specific innovation of the proposed solution, the advantages of the proposed solution over current and emerging areas, and the overall impact on advancing the current state/ baseline if the project is successful. The application should include a justification for the impact assessment approach and impact claim (e.g. performance improvement expectations and ramifications, cost model with references, future market opportunity size, etc.) as well as a description of the pathway to achieve stated impact after the end of the proposed project's period of performance.
Summary Statement of Project Objectives (SOPO)	Provide a succinct description of the specific activities to be conducted over the proposed period of performance. Descriptions should contain enough detail to convey and disclose the work occurring. (Vague statements such as "We will then complete a proprietary process" are unacceptable.) A summary of the general work involved is helpful for the review process, however, spending a tremendous amount of time outlining every detail of the project is not warranted until after selection. It is the applicant's responsibility to prepare an adequately detailed summary SOPO to convince reviewers that the proposed project and team can meet the goals of the funding program. The Summary SOPO should contain the following information:

	• Scope Summary: The applicant should provide a summary description of the overall work scope and approach to achieving the project objectives/goals. The scope summary should describe the work to be accomplished and how the applicant will achieve the milestones and achieve the final project goal(s). • Tasks: It is critical that the overall project objective is broken into separate task sections that are clearly linked to, and combine to result in, the project milestone and final objective. A task is an executable or an operation that is enabled by the collection of subtasks associated with it. As such, tasks represent something more than just the collection of data. Each task description should include a budget amount for each year of proposed work. • (Optional) Sub-tasks may be included if further detail of the breakdown of the work is needed. Each Task may be broken out into component Subtask sections to specify the activities that will be conducted to accomplish the task. A Subtask describes a specific activity that is designed to deliver a device, tool, or technique to collect data. The approach through which the activity is performed is designed to allow the associated task to have a determinant outcome. • Project Schedule (Gantt Chart or similar): The applicant should provide a schedule for the entire project, including task and subtask durations, milestones, and go/no-go decision points. • Milestone Summary Table, or List: • The applicant should provide a summary of appropriate performance targets for the project, termed "milestones." There should be a sufficient number of milestones to demonstrate the applicant understands the steps it will take to achieve the project objectives. • A milestone summary is often helpful for review. Milestones may be consolidated into a single table, list, and/or listed separately at the bottom of the task/subtask description they are relevant to. It is up to the applicant to display milestones in the way that is most appropriate to their proposal. • Include the baseline capability of the applicant team. It is important to document what the team has demonstrated or is building off of to achieve the project objectives. The baseline capability is the effort that can be reliably controlled with an end result that is repeatable. • Include a Go/No-Go Decision Point: The applicant should provide a summary of project-wide go/no-go decision points at the end of each budget period in the Summary SOPO. A go/no-go decision point is a risk management tool and a project management best practice to ensure that, for the current phase or period of performance, project success is definitively achieved and potential for success in future phases or periods of performance is evaluated, prior to actually beginning the execution of future phases. The Applicant should also provide the specific technical criteria to be used to make the go/no-go decision. The summary provided should be consistent with the SOPO. Go/no-go decision points are considered "SMART" and can fulfill the requirement for an annual SMART milestone.

	• Include an End of Project Goal: The applicant should provide a summary of the end of project goal(s). • Milestones should not be activity-based (i.e., provide a report, talk to customers, perform experiments); they should instead be SMART milestones (Specific, Measurable, Achievable, Relevant, and Timely) and must demonstrate a definitive achievement of progress rather than simply performing work. • Milestones should represent achievement of a specific mission-related outcome as opposed to completion of task that may or may not achieve progress towards FOA related goals. "Make 100 phone calls" or "explore three materials" are tasks that could be achieved without any measurable progress toward substantive goals. SETO is not interested in these types of milestones. Conversely, "sell 10 widgets" or "achieve X% efficiency" relies on validation from entities/principles outside of the team's and represent measurable progress towards substantive goals related to the FOA. • Although reports are required as part of the cooperative agreement, they cannot be used as milestones. Reports summarize observations, and milestones validate functionality. • The applicant should also provide the means by which the milestone will be verified. Third-party or unbiased validation is superior to self-verification of results. • These milestones will be carefully reviewed, and their quality is tied to the scoring criteria of this FOA. Imprecise or unambitious milestones will therefore likely result in low scores and non-selection. **Example Summary SOPO Structure** **Scope Summary** [Information articulated in other sections of the Application can be referenced and do not need to be repeated here. Include any new information that is needed to help define and understand the scope of the work required to complete the project. If needed, this space could be used to provide a brief description of the rationale for why the applicant has organized the tasks in the way they have.] **Milestone and Go/No-Go Summary Table** [Optional example format, however, milestones, go/no-go decision points, and end of project goals should be included somewhere in the SOPO Summary in the format most appropriate to the applicant's proposal. Go/no-go decisions points should describe quantifiable metrics that will be achieved at the end of each budget period to demonstrate progress toward achieving overall project goals.]

Milestone #	Months After Project Start		Method to Verify Measurable Result
	0	Define Beginning capability	A method that could not be falsely claimed that shows the result is valid
1	3	Measurable result that retires risk or validates a critical assumption	A method that could not be falsely claimed that shows the result is valid
2	6	II	II
3	6	II	II
4	9	II	II
GO/No-Go Decision Point #1	12	II	II
GO/No-Go Decision Point #2	12	II	II
GO/No-Go Decision Point #3	12	II	II
4	15	II	II
5	18	II	II
6	18	II	II
7	18	II	II
8	21	II	II
End of Project Goal #1	24	II	II
End of Project Goal #2	24	II	II
End of Project Goal #3	24	II	II

Project Schedule:
[Insert Project Schedule (Gantt Chart or similar), applicants may list milestones (with verification process) under the relevant tasks or subtasks and then include in the schedule rather than creating a separate milestone table]

Task 1: Distinctive Title, Date range of the task in months (M1-M4), Estimated total task budget

Task Description: Task summaries shall explicitly identify:

- A concise statement of the objectives of that task
- The work that is to be accomplished and how it will be accomplished (write: "we will" often to structure this in the right way). Tasks should be designed to retire significant risks, such as technology, and manufacturability risks for hardware applications. Each task can address one or multiple risk categories.

(Optional) Subtask 1.1: Distinctive title, Date range (M1-M2)

(Optional)Subtask description: Subtask descriptions:

- Explicitly identify the task objectives/outcomes being addressed and a concise statement of the objectives of that subtask.
- Describe the work and techniques that will be used and the expected result that will be generated from the effort.

	(Optional) Subtask 1.2: Distinctive title, Date range (M2-M7) (Continue until all Task 1 subtasks are listed) **Task 2:** (Continue in the format above until all tasks and subtasks are listed) **Subtask 2.1:**
Team Qualifications and Resources	The Team Qualifications and Resources should contain information such as: • Project Team's unique qualifications and expertise, including those of key Subrecipients (if applicable). • Project Team's existing equipment and facilities that will facilitate the successful completion of the proposed project; include a justification of any new equipment or facilities requested as part of the project. • The time commitment of the key team members to support the project. • The technical services to be provided by DOE/NNSA FFRDCs, if applicable. • The overall approach to and organization for managing the work • The roles of each Project Team member • For multi-organizational or multi-investigator projects: • 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; • How the various efforts will be integrated and managed; • Process for making decisions on scientific/technical direction; • Publication arrangements; • Intellectual Property issues; and • Communication plans
Appendices	• Applicants should attach letters of commitment from all Subrecipient/third party cost share providers as an appendix. Letters of commitment do not count towards the page limit. • Applicants may attach one-page letters of support from other relevant entities (i.e. end users of the proposed solution) as an appendix. Letters of support do not count towards the page limit. Multi-page letters of support are not allowed and will not be reviewed. • Applicants may attach one or two-page resumes for key participating team members as an appendix. Resumes do not count towards the page limit. Resumes over 2 pages are not allowed and will not be reviewed. • Note: Footnotes and endnotes are counted toward the maximum page requirement. Applicants may not include a list of references as an appendix. References and outside links to additional content may be considered by reviewers, however, applications should not require references or outside content to be understood and reviewed.

iii. SF-424: Application for Federal Assistance

Complete all required fields in accordance with the instructions on the form. The list of certifications and assurances in Field 21 can be found at https://energy.gov/eere/funding/eere-funding-application-and-management-

forms, under Negotiation Forms. Note: The dates and dollar amounts on the SF-424 are for the complete project period and not just the first project year, first phase or other subset of the project period. Save the SF-424 in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_App424."

iv. Budget Justification Workbook

- Applicants are required to complete the Budget Justification Workbook. This form is available on EERE Exchange at https://eere-Exchange.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.
- Applicants should include costs associated with required annual audits and incurred cost proposals in their proposed budget documents. The "Instructions and Summary" 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.
- Save the Budget Justification Workbook in a single Microsoft Excel file using the following convention for the title "ControlNumber_LeadOrganization_Budget_Justification."

v. Summary/Abstract for Public Release

Applicants are required to submit a one-page summary/abstract of their project. The project summary/abstract must contain a summary of the proposed activity suitable for dissemination to the public. It should be a self-contained document that identifies the name of the applicant, the project director/principal investigator(s), the project title, the objectives of the project, a description of the project, including methods to be employed, the potential impact of the project (e.g., benefits, outcomes), and major participants (for collaborative projects). This document must not include any proprietary or sensitive business information as DOE may make it available to the public after selections are made. The project summary must not exceed 1 page when printed using standard 8.5 x 11 paper with 1" margins (top, bottom, left, and right) with font not smaller than 12 point. Save the Summary for Public Release in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_Summary."

vi. 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. Save the Summary Slide in a single file using the following convention for the title "ControlNumber_LeadOrganization_Slide."

The Summary Slide template requires the following information:

- A technology summary;
- A description of the technology's impact;
- Proposed project goals;
- Any key graphics (illustrations, charts and/or tables);
- The project's key idea/takeaway;
- Project title, prime recipient, Principal Investigator, and Key Participant information; and
- Requested EERE funds and proposed applicant cost share.

vii. Subrecipient Budget Justification (if applicable)

Applicants must provide a separate budget justification for each subrecipient that is expected to perform work estimated to be more than $250,000 or 25 percent of the total work effort (whichever is less). The budget justification must include the same justification information described in the "Budget Justification" section above. Save each subrecipient budget justification in a Microsoft Excel file using the following convention for the title "ControlNumber_LeadOrganization_Subrecipient_Budget_Justification."

viii. Budget for DOE/NNSA FFRDC (if applicable)

If a DOE/NNSA FFRDC contractor is to perform a portion of the work, the applicant must provide a DOE WP in accordance with the requirements in DOE Order 412.1A, Work Authorization System, Attachment 3, available at: https://www.directives.doe.gov/directives-documents/400-series/0412.1-BOrder-a/@@images/file. Save the WP in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_WP."

ix. Authorization for non-DOE/NNSA or DOE/NNSA FFRDCs (if applicable)

The federal agency sponsoring the FFRDC must authorize in writing the use of the FFRDC on the proposed project and this authorization must be submitted with the application. The use of a FFRDC must be consistent with the contractor's authority under its award. Save the Authorization in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_FFRDCAuth."

x. SF-LLL: Disclosure of Lobbying Activities (required)

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.

Prime recipients and subrecipients are required to complete and submit SF-LLL, "Disclosure of Lobbying Activities" (https://www.grants.gov/web/grants/forms/sf-424-family.html) to ensure that non-federal funds have not been paid and will not be paid to any person for influencing or attempting to influence any of the following in connection with the application:

- An officer or employee of any federal agency
- A member of Congress
- An officer or employee of Congress
- An employee of a member of Congress

Save the SF-LLL in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_SF-LLL."

xi. Waiver Requests: Foreign Entities and Performance of Work in the United States (if applicable)

1. **Foreign Entity Participation:**
   As set forth in Section III.A.iii., all prime recipients receiving funding under this FOA must be incorporated (or otherwise formed) under the laws of a State or territory of the United States. To request a waiver of this requirement, the applicant must submit an explicit waiver request in the Full Application. Appendix C lists the necessary information that must be included in a request to waive this requirement.

2. **Performance of Work in the United States**
   As set forth in Section IV.L.iii., all work under EERE funding agreements must be performed in the United States. This requirement does not apply to the purchase of supplies and equipment, so a waiver is not required for foreign purchases of these items. However, the prime recipient should make every effort to purchase supplies and equipment within the United States. Appendix C lists the necessary information that must be included in a request to waive the Performance of Work in the United States requirement.

Save the Waivers in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_Waiver."

xii. U.S. Manufacturing Commitments

Pursuant to the DOE Determination of Exceptional Circumstances (DEC) dated September 9, 2013, each applicant is required to submit a U.S. Manufacturing Plan as part of its application. The only exceptions will be for Topic 1.2: Small Innovative Projects in Solar and Topic 3: Balance of Systems Soft Cost Reduction applications. The U.S. Manufacturing Plan represents the applicant's measurable commitment to support U.S. manufacturing as a result of its award.

Each U.S. Manufacturing Plan must include a commitment that any products embodying any subject invention or produced through the use of any subject invention will be manufactured substantially in the United States, unless the applicant can show to the satisfaction of DOE that it is not commercially feasible to do so (referred to hereinafter as "the U.S. Competitiveness Provision"). The applicant further agrees to make the U.S. Competitiveness Provision binding on any subawardee and any assignee or licensee or any entity otherwise acquiring rights to any subject invention, including subsequent assignees or licensees. A subject invention is any invention conceived of or first actually reduced to practice under an award.

In lieu of the U.S. Competitiveness Provision, an applicant may propose a U.S. Manufacturing Plan with more specific commitments that would be beneficial to the U.S. economy and competitiveness. For example, an applicant may commit specific products to be manufactured in the U.S., commit to a specific investment in a new or existing U.S. manufacturing facility, keep certain activities based in the U.S. or support a certain number of jobs in the U.S. related to the technology. An applicant which is likely to license the technology to others, especially universities for which licensing may be the exclusive means of commercialization the technology, the U.S. Manufacturing Plan may indicate the applicant's plan and commitment to use a specific licensing strategy that would likely support U.S. manufacturing.

If DOE determines, at its sole discretion, that the more specific commitments would provide a sufficient benefit to the U.S. economy and industrial competitiveness, the specific commitments will be part of the terms and conditions of the award. For all other awards, the U.S. Competitiveness Provision shall be incorporated as part of the terms and conditions of the award as the U.S. Manufacturing Plan for that award.

The U.S. Competitiveness Provision is also a requirement for the Class Patent Waiver that applies to domestic large business under this FOA (see Section VIII.K. Title to Subject Inventions).

Save the U.S. Manufacturing Plan in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_USMP."

For Topics 1.2 and 3, applicants are not required to submit a USMP. To avoid an error message in EERE Exchange, applicants should submit a blank page that says "USMP not required."

xiii. Data Management Plan (DMP)

Applicants whose Full Applications are selected for award negotiations will be required to submit a DMP during the award negotiations phase.

An applicant may select one of the template Data Management Plans (DMP) listed below. Alternatively, instead of selecting one of the template Data Management Plans below, an applicant may submit another DMP provided that the DMP, at a minimum, (1) describes how data sharing and preservation will enable validation of the results from the proposed work, how the results could be validated if data are not shared or preserved and (2) has a plan for making all research data displayed in publications resulting from the proposed work digitally accessible at the time of publications. DOE Public Access Plan dated July 24, 2014 provides additional guidance and information on Data Management Plans.

Option 1 (when protected data is allowed): For the deliverables under the award, the recipient does not plan on making the underlying research data supporting the findings in the deliverables publicly-available for up to 5 years after the data were first produced because such data will be considered protected under the award. The results from the DOE deliverables can be validated by DOE who will have access, upon request, to the research data. Other than providing deliverables as specified in the award, the recipient does not intend to publish the results from the project. However, in an instance where a publication includes results of the project, the underlying research data will be made available according to the policies of the publishing media. Where no such policy exists, the recipient must indicate on the publication a means for requesting and digitally obtaining the underlying research data. This includes the research data necessary to validate any results, conclusions, charts, figures, images in the publications.

Option 2: For any publication that includes results of the project, the underlying research data will be made available according to the policies of the publishing media. Where no such policy exists, the recipient must indicate on the publication a means for requesting and digitally obtaining the underlying research data. This includes the research data necessary to validate any results, conclusions, charts, figures, images in the publications.

Save the DMP in a single Microsoft Word file using the following convention for the title "ControlNumber_LeadOrganization_DMP."

G. Content and Form of Replies to Reviewer Comments

EERE will provide applicants with reviewer comments following evaluation of all eligible Full Applications. Applicants will have a brief opportunity to review the comments and to prepare a short Reply to Reviewer Comments responding to comments however they desire or supplementing their Full Application. The Reply to Reviewer Comments is an optional submission; applicants are not required to submit a Reply to Reviewer Comments. EERE will post the Reviewer Comments in EERE Exchange. The expected submission deadline is on the cover page of the FOA; however, it is the applicant's responsibility to monitor EERE Exchange in the event that the expected date changes. The deadline will not be extended for applicants who are unable to timely submit their reply due to failure to check EERE Exchange or relying on the expected date alone. Applicants should anticipate having approximately three (3) business days to submit Replies to Reviewer Comments.

EERE will not review or consider ineligible Replies to Reviewer Comments (see Section III of the FOA). EERE will review and consider each eligible Full Application, even if no Reply is submitted or if the Reply is found to be ineligible.

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, EERE will review only the first three (3) pages and disregard any additional pages.

SECTION	PAGE LIMIT	DESCRIPTION
Text	Three (3) pages	Applicants may respond to reviewer comments or supplement their Full Application with graphs, charts, or other data.

H. Post Selection Information Requests

If selected for award, EERE reserves the right to request additional or clarifying information regarding the following (non-exhaustive list):

- Indirect cost information

- Other budget information
- Commitment Letters from Third Parties Contributing to Cost Share, if applicable
- Name and phone number of the Designated Responsible Employee for complying with national policies prohibiting discrimination (See 10 CFR 1040.5)
- Representation of Limited Rights Data and Restricted Software, if applicable
- Environmental Questionnaire
- Data Management Plan

I. Dun and Bradstreet Universal Numbering System (DUNS) Number and System for Award Management (SAM)

Each applicant (unless the applicant is an individual or federal awarding agency that is excepted from those requirements under 2 CFR §25.110(b) or (c), or has an exception approved by the federal awarding agency under 2 CFR §25.110(d)) is required to: (1) Be registered in the SAM at https://www.sam.gov before submitting its application; (2) provide a valid DUNS number in its application; and (3) continue to maintain an active SAM registration with current information at all times during which it has an active federal award or an application or plan under consideration by a federal awarding agency. DOE may not make a federal award to an applicant until the applicant has complied with all applicable DUNS and SAM requirements and, if an applicant has not fully complied with the requirements by the time DOE is ready to make a federal award, the DOE will determine that the applicant is not qualified to receive a federal award and use that determination as a basis for making a federal award to another applicant.

J. Submission Dates and Times

Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted in EERE Exchange no later than 5 p.m. Eastern Time on the dates provided on the cover page of this FOA.

K. Intergovernmental Review

This FOA is not subject to Executive Order 12372 – Intergovernmental Review of Federal Programs.

L. Funding Restrictions

i. Allowable Costs

All expenditures must be allowable, allocable, and reasonable in accordance with the applicable federal cost principles.

Refer to the following applicable federal cost principles for more information:

- Federal Acquisition Regulation (FAR) Part 31 for For-Profit entities
- 2 CFR Part 200 Subpart E - Cost Principles for all other non-federal entities

ii. Pre-Award Costs

Selectees must request prior written approval to charge pre-award costs. Pre-award costs are those incurred prior to the effective date of the federal award directly pursuant to the negotiation and in anticipation of the federal award where such costs are necessary for efficient and timely performance of the scope of work. Such costs are allowable only to the extent that they would have been allowable if incurred after the date of the federal award and **only** with the written approval of the federal awarding agency, through the Contracting Officer assigned to the award.

Pre-award costs cannot be incurred prior to the Selection Official signing the Selection Statement and Analysis. Pre-award costs can only be incurred if such costs would be reimbursable under the agreement if incurred after award.

Pre-award expenditures are made at the Selectee's risk. EERE is not obligated to reimburse costs: (1) in the absence of appropriations; (2) if an award is not made; or (3) if an award is made for a lesser amount than the Selectee anticipated.

1. **Pre-Award Costs Related to National Environmental Policy Act (NEPA) Requirements**

   EERE's decision whether and how to distribute federal funds under this FOA is subject to NEPA. Applicants should carefully consider and should seek legal counsel or other expert advice before taking any action related to the proposed project that would have an adverse effect on the environment or limit the choice of reasonable alternatives prior to EERE completing the NEPA review process.

   EERE does not guarantee or assume any obligation to reimburse costs where the prime recipient incurred the costs prior to receiving written authorization from the Contracting Officer. If the applicant elects to undertake activities that may have an adverse effect on the environment or limit the choice of reasonable alternatives prior to receiving such written authorization from the Contracting Officer, the applicant is doing so at risk of not receiving federal funding and such costs may not be recognized as allowable cost share. Likewise, if an application is selected for negotiation of award, and the prime recipient elects to undertake activities that are not authorized for federal funding by the Contracting Officer in advance of EERE completing a NEPA review, the prime recipient is doing so at risk of not receiving federal funding and such costs may not be recognized as allowable cost share. Nothing contained in the pre-award cost reimbursement regulations or any pre-award costs approval letter from the Contracting Officer override these NEPA

requirements to obtain the written authorization from the Contracting Officer prior to taking any action that may have an adverse effect on the environment or limit the choice of reasonable alternatives.

iii. Performance of Work in the United States

1. Requirement

All work performed under EERE awards must be performed in the United States. This requirement does not apply to the purchase of supplies and equipment; however, the prime recipient should make every effort to purchase supplies and equipment within the United States. The prime recipient must flow down this requirement to its subrecipients.

2. Failure to Comply

If the prime recipient fails to comply with the Performance of Work in the United States requirement, EERE may deny reimbursement for the work conducted outside the United States and such costs may not be recognized as allowable recipient cost share. The prime recipient is responsible should any work under this award be performed outside the United States, absent a waiver, regardless of if the work is performed by the prime recipient, subrecipients, contractors or other project partners.

3. Waiver

There may be limited circumstances where it is in the interest of the Project to perform a portion of the work outside the United States. To seek a waiver of the Performance of Work in the United States requirement, the applicant must submit a written waiver request to EERE. Appendix C lists the necessary information that must be included in a request to waive the Performance of Work in the United States requirement.

The applicant must demonstrate to the satisfaction of EERE that a waiver would further the purposes of the FOA and is in the economic interests of the United States. EERE may require additional information before considering a waiver request. Save the waiver request(s) in a single PDF file titled "ControlNumber_LeadOrganization_Waiver." The applicant does not have the right to appeal EERE's decision concerning a waiver request.

iv. Construction

Recipients are required to obtain written authorization from the Contracting Officer before incurring any major construction costs.

v. Foreign Travel

If international travel is proposed for your project, please note that your organization must comply with the International Air Transportation Fair Competitive Practices Act of 1974 (49 USC 40118), commonly referred to as the "Fly America Act," and implementing regulations at 41 CFR 301-10.131 through 301-10.143. The law and regulations require air transport of people or property to, from, between, or within a country other than the United States, the cost of which is supported under this award, to be performed by or under a cost-sharing arrangement with a U.S. flag carrier, if service is available. Foreign travel costs are allowable only with the written prior approval of the Contracting Officer assigned to the award.

vi. Equipment and Supplies

To the greatest extent practicable, all equipment and products purchased with funds made available under this FOA should be American-made. This requirement does not apply to used or leased equipment.

Property disposition will be required at the end of a project if the current fair market value of property exceeds $5,000. The rules for property disposition are set forth in 2 CFR 200.310 – 200.316 as amended by 2 CFR 910.360.

vii. Lobbying

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.

Recipients and subrecipients are required to complete and submit SF-LLL, "Disclosure of Lobbying Activities" (https://www.grants.gov/web/grants/forms/sf-424-family.html) to ensure that non-federal funds have not been paid and will not be paid to any person for influencing or attempting to influence any of the following in connection with the application:

- An officer or employee of any federal agency
- A member of Congress
- An officer or employee of Congress
- An employee of a member of Congress

viii. Risk Assessment

Prior to making a federal award, the DOE is required by 31 U.S.C. 3321 and 41 U.S.C. 2313 to review information available through any Office of Management

and Budget (OMB)-designated repositories of government-wide eligibility qualification or financial integrity information, such as SAM Exclusions and "Do Not Pay."

In addition, DOE evaluates the risk(s) posed by applicants before they receive federal awards. This evaluation may consider: results of the evaluation of the applicant's eligibility; the quality of the application; financial stability; quality of management systems and ability to meet the management standards prescribed in this part; history of performance; reports and findings from audits; and the applicant's ability to effectively implement statutory, regulatory, or other requirements imposed on non-federal entities.

In addition to this review, DOE must comply with the guidelines on government-wide suspension and debarment in 2 CFR 180, and must require non-federal entities to comply with these provisions. These provisions restrict federal awards, subawards and contracts with certain parties that are debarred, suspended or otherwise excluded from or ineligible for participation in federal programs or activities.

ix. Invoice Review and Approval

DOE employs a risk-based approach to determine the level of supporting documentation required for approving invoice payments. Recipients may be required to provide some or all of the following items with their requests for reimbursement:

- Summary of costs by cost categories
- Timesheets or personnel hours report
- Invoices/receipts for all travel, equipment, supplies, contractual, and other costs
- UCC filing proof for equipment acquired with project funds by for-profit recipients and subrecipients
- Explanation of cost share for invoicing period
- Analogous information for some subrecipients
- Other items as required by DOE

V. Application Review Information

A. Technical Review Criteria

i. Concept Papers

Concept Papers are evaluated based on consideration the following factors. All sub-criteria are of equal weight.

Concept Paper Criterion: Overall FOA Responsiveness and Viability of the Project (Weight: 100%)
This criterion involves consideration of the following sub-criteria:

- The applicant clearly describes the proposed technology, describes how the technology is unique and innovative, and how the technology will advance the current state-of-the-art
- The applicant has identified risks and challenges, including possible mitigation strategies, and has shown the impact that EERE funding and the proposed project would have on the relevant field and application
- The applicant has the qualifications, experience, capabilities and other resources necessary to complete the proposed project
- The proposed work, if successfully accomplished, would clearly meet the objectives as stated in the FOA

ii. Full and SIPS Applications

Full and SIPS Applications (SIPS is Topic 1.2) will be evaluated against the merit review criteria shown below.

Criterion 1: Innovation and Impact (50%)

The project is innovative and impactful, assuming the stated outcomes can be achieved as written. The project is differentiated with respect to existing commercial products, solutions, or technologies. If successful, the project is scalable to have a broader impact and maintained at a sufficiently large scale after project completion.

Criterion 2: Quality and Likelihood of Completion of Stated Goals (30%)
The application demonstrates an understanding and appreciation of project risks and challenges the proposed work will face and incorporates reasonable assumptions related to the execution of the project (i.e. market size, customer participation, costs, speed of proposed scale-up or adoption). The information included for the project is validated through customer trials, data from prior work, report references, technical baselines established, etc. The stated goals of the project are SMART (Specific, Measurable, Achievable, Relevant, and Timely) and likely to be accomplished within the scope of this project. The proposed budget is reasonable to achieve the objectives proposed.

Criterion 3: Capability and Resources of the Applicant/Project Team (20%)
The team is well qualified and has the capability and resources necessary to successfully complete the project. The team (including proposed subrecipients) have the training and experience to achieve the final results on time and to

specification. The project team is fully assembled and committed to the project (verified through letters of support) and has a demonstrated record of successful past performance.

iii. Criteria for Replies to Reviewer Comments

EERE has not established separate criteria to evaluate Replies to Reviewer Comments. Instead, Replies to Reviewer Comments are attached to the original applications and evaluated as an extension of the Full Application.

B. Standards for Application Evaluation

Applications that are determined to be eligible will be evaluated in accordance with this FOA, by the standards set forth in EERE's Notice of Objective Merit Review Procedure (76 Fed. Reg. 17846, March 31, 2011) and the guidance provided in the "DOE Merit Review Guide for Financial Assistance," effective April 14, 2017, which is available at: https://energy.gov/management/downloads/merit-review-guide-financial-assistance-and-unsolicited-proposals-current.

C. Other Selection Factors

i. Program Policy Factors

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

- The degree to which the proposed project exhibits technological or programmatic diversity when compared to the existing DOE project portfolio and other projects selected from the subject FOA
- The degree to which the proposed project, including proposed cost share, optimizes the use of available EERE funding to achieve programmatic objectives
- The level of industry involvement and demonstrated ability to accelerate commercialization and overcome key market barriers
- Based on the commitments made in the U.S. Manufacturing Plan, the degree to which the proposed project is likely to lead to increased employment and manufacturing in the United States or provide other economic benefit to U.S. taxpayers
- The degree to which the proposed project will accelerate transformational technological, financial, or other advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty
- The degree to which the proposed project, or group of projects, represent a desired geographic distribution (considering past awards and current applications)

- The degree to which the proposed project avoids duplication/overlap with other publicly or privately funded work
- The degree to which the proposed project enables new and expanding market segments
- The degree to which the project promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer

D. Evaluation and Selection Process

i. Overview

The evaluation process consists of multiple phases; each includes an initial eligibility review and a thorough technical review. Rigorous technical reviews of eligible submissions are conducted by reviewers that are experts in the subject matter of the FOA. Ultimately, the Selection Official considers the recommendations of the reviewers, along with other considerations such as program policy factors, in determining which applications to select.

ii. Pre-Selection Interviews

As part of the evaluation and selection process, EERE may invite one or more applicants to participate in Pre-Selection Interviews. Pre-Selection Interviews are distinct from and more formal than pre-selection clarifications (See Section V.D.iii. of the FOA). The invited applicant(s) will meet with EERE representatives to provide clarification on the contents of the Full Applications and to provide EERE an opportunity to ask questions regarding the proposed project. The information provided by applicants to EERE through Pre-Selection Interviews contributes to EERE's selection decisions.

EERE will arrange to meet with the invited applicants in person at EERE's offices or a mutually agreed upon location. EERE may also arrange site visits at certain applicants' facilities. In the alternative, EERE may invite certain applicants to participate in a one-on-one conference with EERE via webinar, videoconference, or conference call.

EERE will not reimburse applicants for travel and other expenses relating to the Pre-Selection Interviews, nor will these costs be eligible for reimbursement as pre-award costs.

EERE may obtain additional information through Pre-Selection Interviews that will be used to make a final selection determination. EERE may select applications for funding and make awards without Pre-Selection Interviews. Participation in Pre-Selection Interviews with EERE does not signify that applicants have been selected for award negotiations.

iii. Pre-Selection Clarification

EERE may determine that pre-selection clarifications are necessary from one or more applicants. Pre-selection clarifications are distinct from and less formal than pre-selection interviews. These pre-selection clarifications will solely be for the purposes of clarifying the application, and will be limited to information already provided in the application documentation. The pre-selection clarifications may occur before, during or after the merit review evaluation process. Information provided by an applicant that is not necessary to address the pre-selection clarification question will not be reviewed or considered. Typically, a pre-selection clarification will be carried out through either written responses to EERE's written clarification questions or video or conference calls with EERE representatives.

The information provided by applicants to EERE through pre-selection clarifications is incorporated in their applications and contributes to the merit review evaluation and EERE's selection decisions. If EERE contacts an applicant for pre-selection clarification purposes, it does not signify that the applicant has been selected for negotiation of award or that the applicant is among the top ranked applications.

EERE will not reimburse applicants for expenses relating to the pre-selection clarifications, nor will these costs be eligible for reimbursement as pre-award costs.

iv. Recipient Integrity and Performance Matters

DOE, prior to making a federal award with a total amount of federal share greater than the simplified acquisition threshold, is required to review and consider any information about the applicant that is in the designated integrity and performance system accessible through SAM (currently FAPIIS) (see 41 U.S.C. 2313).

The applicant, at its option, may review information in the designated integrity and performance systems accessible through SAM and comment on any information about itself that a federal awarding agency previously entered and is currently in the designated integrity and performance system accessible through SAM.

DOE will consider any written comments by the applicant, in addition to the other information in the designated integrity and performance system, in making a judgment about the applicant's integrity, business ethics, and record of

performance under federal awards when completing the review of risk posed by applicants as described in 2 C.F.R. § 200.205.

v. Selection

The Selection Official may consider the technical merit, the Federal Consensus Board's recommendations, program policy factors, and the amount of funds available in arriving at selections for this FOA.

E. Anticipated Notice of Selection and Award Negotiation Dates

EERE anticipates notifying applicants selected for negotiation of award and negotiating awards by the dates provided on the cover page of this FOA.

VI. Award Administration Information

A. Award Notices

i. Ineligible Submissions

Ineligible Concept Papers and Full Applications will not be further reviewed or considered for award. The Contracting Officer will send a notification letter by email to the technical and administrative points of contact designated by the applicant in EERE Exchange. The notification letter will state the basis upon which the Concept Paper or the Full Application is ineligible and not considered for further review.

ii. Concept Paper Notifications

EERE will notify applicants of its determination to encourage or discourage the submission of a Full Application. EERE will post these notifications to EERE Exchange.

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, EERE intends to convey its lack of programmatic interest in the proposed project. Such assessments do not necessarily reflect judgments on the merits of the proposed project. The purpose of the Concept Paper phase is to save applicants the considerable time and expense of preparing a Full Application that is unlikely to be selected for award negotiations.

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

iii. Full Application Notifications

EERE will notify applicants of its determination via a notification letter by email to the technical and administrative points of contact designated by the applicant in EERE Exchange. The notification letter will inform the applicant whether or not its Full Application was selected for award negotiations. Alternatively, EERE 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.

iv. Successful Applicants

Receipt of a notification letter selecting a Full Application for award negotiations does not authorize the applicant to commence performance of the project. If an application is selected for award negotiations, it is not a commitment by EERE to issue an award. Applicants do not receive an award until award negotiations are complete and the Contracting Officer executes the funding agreement, accessible by the prime recipient in FedConnect.

The award negotiation process will take approximately 60 days. Applicants must designate a primary and a backup point-of-contact in EERE Exchange with whom EERE will communicate to conduct award negotiations. The applicant must be responsive during award negotiations (i.e., provide requested documentation) and meet the negotiation deadlines. If the applicant fails to do so or if award negotiations are otherwise unsuccessful, EERE will cancel the award negotiations and rescind the Selection. EERE reserves the right to terminate award negotiations at any time for any reason.

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

v. Alternate Selection Determinations

In some instances, an applicant may receive a notification that its application was not selected for award and EERE designated the application to be an alternate. As an alternate, EERE may consider the Full Application for federal funding in the future. A notification letter stating the Full Application is designated as an alternate does not authorize the applicant to commence performance of the project. EERE may ultimately determine to select or not select the Full Application for award negotiations.

vi. Unsuccessful Applicants

EERE shall promptly notify in writing each applicant whose application has not been selected for award or whose application cannot be funded because of the unavailability of appropriated funds.

B. Administrative and National Policy Requirements

i. Registration Requirements

There are several one-time actions before submitting an application in response to this FOA, and it is vital that applicants address these items as soon as possible. Some may take several weeks, and failure to complete them could interfere with an applicant's ability to apply to this FOA, or to meet the negotiation deadlines and receive an award if the application is selected. These requirements are as follows:

1. **EERE Exchange**
   Register and create an account on EERE Exchange at https://eere-Exchange.energy.gov.
   This account will then allow the user to register for any open EERE FOAs that are currently in EERE Exchange. It is recommended that each organization or business unit, whether acting as a team or a single entity, use only one account as the contact point for each submission. Applicants should also designate backup points of contact so they may be easily contacted if deemed necessary. **This step is required to apply to this FOA.**

   The EERE Exchange registration does not have a delay; however, **the remaining registration requirements below could take several weeks to process and are necessary for a potential applicant to receive an award under this FOA**.

2. **DUNS Number**
   Obtain a DUNS number (including the plus 4 extension, if applicable) at http://fedgov.dnb.com/webform.

3. **System for Award Management**
   Register with the SAM at https://www.sam.gov. Designating an Electronic Business Point of Contact (EBiz POC) and obtaining a special password called an Marketing Partner ID Number (MPIN) are important steps in SAM registration. Please update your SAM registration annually.

4. **FedConnect**
   Register in FedConnect at https://www.fedconnect.net. To create an organization account, your organization's SAM MPIN is required. For more information about the SAM MPIN or other registration requirements, review the FedConnect Ready, Set, Go! Guide at https://www.fedconnect.net/FedConnect/Marketing/Documents/FedConnect_Ready_Set_Go.pdf.

5. **Grants.gov**
   Register in Grants.gov (http://www.grants.gov) to receive automatic updates when Amendments to this FOA are posted. However, please note that LOI, Concept Papers, and Full Applications will not be accepted through Grants.gov.

6. **Electronic Authorization of Applications and Award Documents**
   Submission of an application and supplemental information under this FOA through electronic systems used by the DOE, including EERE Exchange and FedConnect.net, constitutes the authorized representative's approval and electronic signature.

ii. Award Administrative Requirements

The administrative requirements for DOE grants and cooperative agreements are contained in 2 CFR Part 200 as amended by 2 CFR Part 910.

iii. Foreign National Access to DOE Sites

All applicants that ultimately enter into an award resulting from this FOA will be subject to the following requirement concerning foreign national involvement. Upon DOE's request, prime recipients must provide information to facilitate DOE's responsibilities associated with foreign national access to DOE sites, information, technologies, and equipment. A foreign national is defined as any person who was born outside the jurisdiction of the United States, is a citizen of a foreign government, and has not been naturalized under U.S. law. If the prime recipient or subrecipients, contractors or vendors under the award, anticipate utilizing a foreign national person in the performance of an award, the prime recipient is responsible for providing to the Contracting Officer specific information of the foreign national(s) to satisfy compliance with all of the requirements for access approval.

iv. Subaward and Executive Reporting

Additional administrative requirements necessary for DOE grants and cooperative agreements to comply with the Federal Funding and Transparency Act of 2006 (FFATA) are contained in 2 CFR Part 170. Prime recipients must register with the new FFATA Subaward Reporting System database and report the required data on their first tier subrecipients. Prime recipients must report the executive compensation for their own executives as part of their registration profile in SAM.

v. National Policy Requirements

The National Policy Assurances that are incorporated as a term and condition of award are located at: http://www.nsf.gov/awards/managing/rtc.jsp.

vi. Environmental Review in Accordance with National Environmental Policy Act (NEPA)

EERE's decision whether and how to distribute federal funds under this FOA is subject to NEPA (42 USC 4321, *et seq.*). NEPA requires federal agencies to integrate environmental values into their decision-making processes by considering the potential environmental impacts of their proposed actions. For additional background on NEPA, please see DOE's NEPA website, at http://nepa.energy.gov/.

While NEPA compliance is a federal agency responsibility and the ultimate decisions remain with the federal agency, all recipients selected for an award will be required to assist in the timely and effective completion of the NEPA process in the manner most pertinent to their proposed project. If DOE determines certain records must be prepared to complete the NEPA review process (e.g., biological evaluations or environmental assessments), the costs to prepare the necessary records may be included as part of the project costs.

vii. Applicant Representations and Certifications

1. Lobbying Restrictions

By accepting funds under this award, the prime recipient agrees that none of the funds obligated on the award shall be expended, directly or indirectly, to influence Congressional action on any legislation or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. §1913. This restriction is in addition to those prescribed elsewhere in statute and regulation.

2. Corporate Felony Conviction and Federal Tax Liability Representations

In submitting an application in response to this FOA, the applicant represents that:

a. It is **not** a corporation that has been convicted of a felony criminal violation under any federal law within the preceding 24 months, and

b. It is **not** a corporation that has any unpaid federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely

manner pursuant to an agreement with the authority responsible for collecting the tax liability.

For purposes of these representations the following definitions apply:

A Corporation includes any entity that has filed articles of incorporation in any of the 50 states, the District of Columbia, or the various territories of the United States [but not foreign corporations]. It includes both for-profit and non-profit organizations.

3. Nondisclosure and Confidentiality Agreements Representations
In submitting an application in response to this FOA the applicant represents that:

a. It **does not and will not** require its employees or contractors to sign internal nondisclosure or confidentiality agreements or statements prohibiting or otherwise restricting its employees or contactors from lawfully reporting waste, fraud, or abuse to a designated investigative or law enforcement representative of a federal department or agency authorized to receive such information.

b. It **does not and will not** use any federal funds to implement or enforce any nondisclosure and/or confidentiality policy, form, or agreement it uses unless it contains the following provisions:

(1) *''These provisions are consistent with and do not supersede, conflict with, or otherwise alter the employee obligations, rights, or liabilities created by existing statute or Executive order relating to (1) classified information, (2) communications to Congress, (3) the reporting to an Inspector General of a violation of any law, rule, or regulation, or mismanagement, a gross waste of funds, an abuse of authority, or a substantial and specific danger to public health or safety, or (4) any other whistleblower protection. The definitions, requirements, obligations, rights, sanctions, and liabilities created by controlling Executive orders and statutory provisions are incorporated into this agreement and are controlling.''*

(2) The limitation above shall not contravene requirements applicable to Standard Form 312 Classified Information Nondisclosure Agreement (https://fas.org/sgp/othergov/sf312.pdf), Form 4414 Sensitive Compartmented Information Disclosure Agreement (https://fas.org/sgp/othergov/intel/sf4414.pdf),

or any other form issued by a federal department or agency governing the nondisclosure of classified information.

(3) Notwithstanding the provision listed in paragraph (a), a nondisclosure or confidentiality policy form or agreement that is to be executed by a person connected with the conduct of an intelligence or intelligence-related activity, other than an employee or officer of the United States Government, may contain provisions appropriate to the particular activity for which such document is to be used. Such form or agreement shall, at a minimum, require that the person will not disclose any classified information received in the course of such activity unless specifically authorized to do so by the United States Government. Such nondisclosure or confidentiality forms shall also make it clear that they do not bar disclosures to Congress, or to an authorized official of an executive agency or the Department of Justice, that are essential to reporting a substantial violation of law.

viii. Statement of Federal Stewardship

EERE will exercise normal federal stewardship in overseeing the project activities performed under EERE awards. Stewardship Activities include, but are not limited to, conducting site visits; reviewing performance and financial reports; providing assistance and/or temporary intervention in unusual circumstances to correct deficiencies that develop during the project; assuring compliance with terms and conditions; and reviewing technical performance after project completion to ensure that the project objectives have been accomplished.

ix. Statement of Substantial Involvement

EERE has substantial involvement in work performed under awards made as a result of this FOA. EERE does not limit its involvement to the administrative requirements of the award. Instead, EERE has substantial involvement in the direction and redirection of the technical aspects of the project as a whole. Substantial involvement includes, but is not limited to, the following:

1. EERE shares responsibility with the recipient for the management, control, direction, and performance of the project.

2. EERE may intervene in the conduct or performance of work under this award for programmatic reasons. Intervention includes the interruption or modification of the conduct or performance of project activities.

3. EERE may redirect or discontinue funding the project based on the outcome of EERE's evaluation of the project at the Go/No-Go decision point(s).

4. EERE participates in major project decision-making processes.

x. Subject Invention Utilization Reporting

In order to ensure that prime recipients and subrecipients holding title to subject inventions are taking the appropriate steps to commercialize subject inventions, EERE may require that each prime recipient holding title to a subject invention submit annual reports for 10 years from the date the subject invention was disclosed to EERE on the utilization of the subject invention and efforts made by prime recipient or their licensees or assignees to stimulate such utilization. The reports must include information regarding the status of development, date of first commercial sale or use, gross royalties received by the prime recipient, and such other data and information as EERE may specify.

xi. Intellectual Property Provisions

The standard DOE financial assistance intellectual property provisions applicable to the various types of recipients are located at http://energy.gov/gc/standard-intellectual-property-ip-provisions-financial-assistance-awards.

xii. Reporting

Reporting requirements are identified on the Federal Assistance Reporting Checklist, attached to the award agreement. This helpful EERE checklist can be accessed at https://www.energy.gov/eere/funding/eere-funding-application-and-management-forms. See Attachment 2 Federal Assistance Reporting Checklist, after clicking on "Model Cooperative Agreement" under the Award Package section.

xiii. Go/No-Go Review

Each project selected under this FOA will be subject to a periodic project evaluation referred to as a Go/No-Go Review. At the Go/No-Go decision points, EERE will evaluate project performance, project schedule adherence, meeting milestone objectives, compliance with reporting requirements, and overall contribution to the EERE program goals and objectives. Federal funding beyond the Go/No-Go decision point (continuation funding) is contingent upon (1) availability of federal funds appropriated by Congress for the purpose of this program; (2) the availability of future-year budget authority; (3) recipient's technical progress compared to the Milestone Summary Table stated in Attachment 1 of the award; (4) recipient's submittal of required reports; (5) recipient's compliance with the terms and conditions of the award; (6) EERE's Go/No-Go decision; (7) the recipient's submission of a continuation application;

and (8) written approval of the continuation application by the Contracting Officer.

As a result of the Go/No-Go Review, DOE may, at its discretion, authorize the following actions: (1) continue to fund the project, contingent upon the availability of funds appropriated by Congress for the purpose of this program and the availability of future-year budget authority; (2) recommend redirection of work under the project; (3) place a hold on federal funding for the project, pending further supporting data or funding; or (4) discontinue funding the project because of insufficient progress, change in strategic direction, or lack of funding.

The Go/No-Go decision is distinct from a non-compliance determination. In the event a recipient fails to comply with the requirements of an award, EERE may take appropriate action, including but not limited to, redirecting, suspending or terminating the award.

xiv. Conference Spending

The recipient shall not expend any funds on a conference not directly and programmatically related to the purpose for which the grant or cooperative agreement was awarded that would defray the cost to the United States Government of a conference held by any Executive branch department, agency, board, commission, or office for which the cost to the United States Government would otherwise exceed $20,000, thereby circumventing the required notification by the head of any such Executive Branch department, agency, board, commission, or office to the Inspector General (or senior ethics official for any entity without an Inspector General), of the date, location, and number of employees attending such conference.

xv. Uniform Commercial Code (UCC) Financing Statements

Per 2 CFR 910.360 (Real Property and Equipment) when a piece of equipment is purchased by a for-profit recipient or subrecipient with federal funds, and when the federal share of the financial assistance agreement is more than $1,000,000, the recipient or subrecipient must:

Properly record, and consent to the Department's ability to properly record if the recipient fails to do so, UCC financing statement(s) for all equipment in excess of $5,000 purchased with project funds. These financing statement(s) must be approved in writing by the Contracting Officer prior to the recording, and they shall provide notice that the recipient's title to all equipment (not real property) purchased with federal funds under the financial assistance agreement is conditional pursuant to the terms of this section, and that the Government

retains an undivided reversionary interest in the equipment. The UCC financing statement(s) must be filed before the Contracting Officer may reimburse the recipient for the federal share of the equipment unless otherwise provided for in the relevant financial assistance agreement. The recipient shall further make any amendments to the financing statements or additional recordings, including appropriate continuation statements, as necessary or as the Contracting Officer may direct.

C. Program Down-Select

In addition to the Go/No-Go Reviews required for each project, EERE intends to conduct a competitive project review (down-selection process) upon the completion of the first two and a half years of work of the Photovoltaics Research Collaborations (Topic 1.1). Recipients will present their projects to EERE individually (not to other recipients). Subject matter experts from academia, national laboratories, and industry may be used as reviewers, subject to conflict of interest and non-disclosure considerations. Projects will be evaluated based on the following criteria areas:

- Overall progress toward completing research milestones and goals
- Quality of the proposed detailed workplan for years 4-5 of the award
- Research capabilities of the team to demonstrate and advance the state of the art
- Synergistic value of the collaboration to achieve more than individual research projects

Detailed review criteria will be supplied to awardees along with the request for the down-select review materials. Upon completion of the competitive project review (down-selection process), EERE will select which projects will receive federal funding beyond the third year. Due to the availability of funding and program considerations, only a portion of the recipients will be selected to receive funding for project continuation. As a result of this down-select process, certain projects will not receive federal funding beyond the third year even if the project is meeting the pre-defined metrics.

VII. Questions/Agency Contacts

Upon the issuance of a FOA, EERE personnel are prohibited from communicating (in writing or otherwise) with applicants regarding the FOA except through the established question and answer process as described below. Specifically, questions regarding the content of this FOA must be submitted to: *SETO.FOA@ee.doe.gov*. Questions must be submitted not later than 3 business days prior to the application due date and time. Please note, feedback on individual concepts will not be provided through Q&A.

All questions and answers related to this FOA will be posted on EERE Exchange at: https://eere-exchange.energy.gov. **Please note that you must first select this specific FOA Number in order to view the questions and answers specific to this FOA**. EERE will attempt to respond to a question within 3 business days, unless a similar question and answer has already been posted on the website.

Questions related to the registration process and use of the EERE Exchange website should be submitted to: EERE-ExchangeSupport@hq.doe.gov.

VIII. Other Information

A. FOA Modifications

Amendments to this FOA will be posted on the EERE Exchange website and the Grants.gov system. However, you will only receive an email when an amendment or a FOA is posted on these sites if you register for email notifications for this FOA in Grants.gov. EERE recommends that you register as soon after the release of the FOA as possible to ensure you receive timely notice of any amendments or other FOAs.

B. Government Right to Reject or Negotiate

EERE reserves the right, without qualification, to reject any or all applications received in response to this FOA and to select any application, in whole or in part, as a basis for negotiation and/or award.

C. Commitment of Public Funds

The Contracting Officer is the only individual who can make awards or commit the Government to the expenditure of public funds. A commitment by anyone other than the Contracting Officer, either express or implied, is invalid.

D. Treatment of Application Information

In general, EERE will only use data and other information contained in applications for evaluation purposes, unless such information is generally available to the public or is already the property of the Government.

Applicants should not include trade secrets or commercial or financial information that is privileged or confidential in their application unless such information is necessary to convey an understanding of the proposed project or to comply with a requirement in the FOA.

The use of protective markings such as “Do Not Publicly Release – Trade Secret” or “Do Not Publicly Release – Confidential Business Information” is encouraged. However, applicants should be aware that the use of protective markings is not

dispositive as to whether information will be publicly released pursuant to the Freedom of Information Act, 5 U.S.C. §552, et. seq., as amended by the OPEN Government Act of 2007, Pub. L. No. 110-175. (See Section I of this document, "Notice of Potential Disclosure Under the Freedom of Information Act (FOIA)" for additional information regarding the public release of information under FOIA.

Applicants are encouraged to employ protective markings in the following manner:

The cover sheet of the application must be marked as follows and identify the specific pages containing trade secrets or commercial or financial information that is privileged or confidential:

Notice of Restriction on Disclosure and Use of Data:
Pages [list applicable pages] of this document may contain trade secrets or commercial or financial information that is privileged or confidential, and 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. [End of Notice]

The header and footer of every page that contains trade secrets or commercial or financial information that is privileged must be marked as follows: "May contain trade secrets or commercial or financial information that is privileged or confidential and exempt from public disclosure."

In addition, each line or paragraph containing trade secrets or commercial or financial information that is privileged or confidential must be enclosed in brackets.

E. Evaluation and Administration by Non-Federal Personnel

In conducting the merit review evaluation, the Go/No-Go Review and Peer Review, the Government may seek the advice of qualified non-federal personnel as reviewers. The Government may also use non-federal personnel to conduct routine, nondiscretionary administrative activities, including EERE contractors. The applicant, by submitting its application, consents to the use of non-federal reviewers/administrators. Non-federal reviewers must sign conflict of interest (COI) and non-disclosure acknowledgements (NDA) prior to reviewing an application. Non-federal personnel conducting administrative activities must sign an NDA.

F. Notice Regarding Eligible/Ineligible Activities

Eligible activities under this FOA include those which describe and promote the understanding of scientific and technical aspects of specific energy technologies, but

not those which encourage or support political activities such as the collection and dissemination of information related to potential, planned or pending legislation.

G. Notice of Right to Conduct a Review of Financial Capability

EERE reserves the right to conduct an independent third party review of financial capability for applicants that are selected for negotiation of award (including personal credit information of principal(s) of a small business if there is insufficient information to determine financial capability of the organization).

H. Notice of Potential Disclosure Under Freedom of Information Act (FOIA)

Under the FOIA, 5 U.S.C. §552, et. seq., as amended by the OPEN Government Act of 2007, Pub. L. No. 110-175, any information received from the applicant is considered to be an agency record, and as such, subject to public release under FOIA. The purpose of the FOIA is to afford the public the right to request and receive agency records unless those agency records are protected from disclosure under one or more of the nine FOIA exemptions. Decisions to disclose or withhold information received from the applicant are based upon the applicability of one or more of the nine FOIA exemptions, not on the existence or nonexistence of protective markings or designations. Only the agency's designated FOIA Officer may determine if information received from the applicant may be withheld pursuant to one of the nine FOIA exemptions. All FOIA requests received by DOE are processed in accordance with 10 C.F.R. Part 1004.

I. Requirement for Full and Complete Disclosure

Applicants are required to make a full and complete disclosure of all information requested. Any failure to make a full and complete disclosure of the requested information may result in:

- 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.

J. Retention of Submissions

EERE expects to retain copies of all LOI, Concept Papers, Full Applications, Replies to Reviewer Comments, and other submissions. No submissions will be returned. By

applying to EERE for funding, applicants consent to EERE's retention of their submissions.

K. Title to Subject Inventions

Ownership of subject inventions is governed pursuant to the authorities listed below:

- 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;
- 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 Patent Waiver: DOE has issued a class waiver that applies to this FOA. Under this class waiver, domestic large businesses may elect title to their subject inventions similar to the right provided to the domestic small businesses, educational institutions, and nonprofits by law. In order to avail itself of the class waiver, a domestic large business must agree that any products embodying or produced through the use of a subject invention first created or reduced to practice under this program will be substantially manufactured in the United States, unless DOE agrees that the commitments proposed in the U.S. Manufacturing Plan are sufficient.
- Advance and Identified Waivers: Applicants may request a patent waiver that will cover subject inventions that may be invented under the award, in advance of or within 30 days after the effective date of the award. Even if an advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver for identified inventions, i.e., individual subject inventions that are disclosed to EERE within the timeframes set forth in the award's intellectual property terms and conditions. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784; and
- DEC: Each applicant is required to submit a U.S. Manufacturing Plan as part of its application, with the exception of Topic 1.2 and Topic 3. If selected, the U.S. Manufacturing Plan shall be incorporated into the award terms and conditions for domestic small businesses and nonprofit organizations. DOE has determined that exceptional circumstances exist that warrants the modification of the standard patent rights clause for small businesses and non-profit awardees under Bayh-Dole to the extent necessary to implement and enforce the U.S. Manufacturing Plan. Any Bayh-Dole entity (domestic small business or nonprofit organization) affected by this DEC has the right to appeal it.

L. 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 to a third party. In addition, the Government may grant licenses for use of the subject invention when a prime recipient, subrecipient, or their assignees and exclusive licensees refuse to do so.

DOE may exercise its march-in rights only 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 satisfied manner;
- The owner has not met public use requirements specified by federal statutes in a reasonably satisfied manner; or
- The U.S. Manufacturing requirement has not been met.

Any determination that march-in rights are warranted must follow a fact-finding process in which the recipient has certain rights to present evidence and witnesses, confront witnesses and appear with counsel and appeal any adverse decision. To date, DOE has never exercised its march-in rights to any subject inventions.

M. 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.

"Limited Rights Data": The U.S. Government will not normally require delivery of confidential or trade secret-type 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.

Government Rights in Technical Data Produced Under Awards: The U.S. Government normally retains unlimited 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 EERE awards may be protected from public disclosure for up to five years after the data is generated ("Protected Data"). For awards permitting Protected Data, the protected data must be marked as set forth in the awards intellectual property terms and conditions and a listing of unlimited rights data (i.e., non-protected data) must be inserted into the data clause in the award. In addition, invention disclosures may be protected from public disclosure for a reasonable time in order to allow for filing a patent application.

N. Copyright

The prime recipient and subrecipients may assert copyright in copyrightable works, such as software, first produced under the award without EERE approval. When copyright is asserted, the Government retains a paid-up nonexclusive, irrevocable worldwide license to reproduce, prepare derivative works, distribute copies to the public, and to perform publicly and display publicly the copyrighted work. This license extends to contractors and others doing work on behalf of the Government.

O. Personally Identifiable Information (PII)

All information provided by the applicant must to the greatest extent possible exclude PII. The term "PII" refers to information which can be used to distinguish or trace an individual's identity, such as their name, social security number, biometric records, alone, or when combined with other personal or identifying information which is linked or linkable to a specific individual, such as date and place of birth, mother's maiden name. (See OMB Memorandum M-07-16 dated May 22, 2007, found at: https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/memoranda/2007/m07-16.pdf

By way of example, applicants must screen resumes to ensure that they do not contain PII such as personal addresses, personal landline/cell phone numbers, and personal emails. **Under no circumstances should Social Security Numbers (SSNs) be included in the application**. Federal Agencies are prohibited from the collecting, using, and displaying unnecessary SSNs. (See, the Federal Information Security Modernization Act of 2014 (Pub. L. No. 113-283, Dec 18, 2014; 44 U.S.C. §3551).

P. Annual Independent Audits

If a for-profit entity is a prime recipient and has expended $750,000 or more of DOE awards during the entity's fiscal year, an annual compliance audit performed by an independent auditor is required. For additional information, please refer to 2 C.F.R. § 910.501 and Subpart F.

If an educational institution, non-profit organization, or state/local government is a prime recipient or subrecipient and has expended $750,000 or more of federal awards during the non-federal entity's fiscal year, then a Single or Program-Specific Audit is required. For additional information, please refer to 2 C.F.R. § 200.501 and Subpart F.

Applicants and subrecipients (if applicable) should propose sufficient costs in the project budget to cover the costs associated with the audit. EERE will share in the cost of the audit at its applicable cost share ratio.

Q. Informational Webinar

EERE will conduct five informational webinars during the FOA process. One webinar will be held for each topic area. It will be held after the initial FOA release but before the due date for Concept Papers.

Attendance is not mandatory and will not positively or negatively impact the overall review of any applicant submissions. As the webinar will be open to all applicants who wish to participate, applicants should refrain from asking questions or communicating information that would reveal confidential and/or proprietary information specific to their project. Specific dates for the webinar can be found on EERE Exchange.

APPENDIX A – COST SHARE INFORMATION

Cost Sharing or Cost Matching

The terms "cost sharing" and "cost matching" are often used synonymously. Even the DOE Financial Assistance Regulations, 2 CFR 200.306, use both of the terms in the titles specific to regulations applicable to cost sharing. EERE almost always uses the term "cost sharing," as it conveys the concept that non-federal share is calculated as a percentage of the Total Project Cost. An exception is the State Energy Program Regulation, 10 CFR 420.12, State Matching Contribution. Here "cost matching" for the non-federal share is calculated as a percentage of the federal funds only, rather than the Total Project Cost.

How Cost Sharing Is Calculated

As stated above, cost sharing is calculated as a percentage of the Total Project Cost. FFRDC costs must be included in Total Project Costs. The following is an example of how to calculate cost sharing amounts for a project with $1,000,000 in federal funds with a minimum 20% non-federal cost sharing requirement:

- Formula: Federal share ($) divided by federal share (%) = Total Project Cost
  Example: $1,000,000 divided by 80% = $1,250,000

- Formula: Total Project Cost ($) minus federal share ($) = Non-federal share ($)
  Example: $1,250,000 minus $1,000,000 = $250,000

- Formula: Non-federal share ($) divided by Total Project Cost ($) = Non-federal share (%)
  Example: $250,000 divided by $1,250,000 = 20%

What Qualifies For Cost Sharing

While it is not possible to explain what specifically qualifies for cost sharing in one or even a couple of sentences, in general, if a cost is allowable under the cost principles applicable to the organization incurring the cost and is eligible for reimbursement under an EERE grant or cooperative agreement, then it is allowable as cost share. Conversely, if the cost is not allowable under the cost principles and not eligible for reimbursement, then it is not allowable as cost share. In addition, costs may not be counted as cost share if they are paid by the federal Government under another award unless authorized by federal statute to be used for cost sharing.

The rules associated with what is allowable as cost share are specific to the type of organization that is receiving funds under the grant or cooperative agreement, though are generally the same for all types of entities. The specific rules applicable to:

- FAR Part 31 for For-Profit entities, (48 CFR Part 31); and
- 2 CFR Part 200 Subpart E - Cost Principles for all other non-federal entities.

In addition to the regulations referenced above, other factors may also come into play such as timing of donations and length of the project period. For example, the value of ten years of donated maintenance on a project that has a project period of five years would not be fully allowable as cost share. Only the value for the five years of donated maintenance that corresponds to the project period is allowable and may be counted as cost share.

Additionally, EERE generally does not allow pre-award costs for either cost share or reimbursement when these costs precede the signing of the appropriation bill that funds the award. In the case of a competitive award, EERE generally does not allow pre-award costs prior to the signing of the Selection Statement by the EERE Selection Official.

General Cost Sharing Rules on a DOE Award

1. Cash Cost Share - encompasses all contributions to the project made by the recipient or subrecipient(s), for costs incurred and paid for during the project. This includes when an organization pays for personnel, supplies, equipment for their own company with organizational resources. If the item or service is reimbursed for, it is cash cost share. All cost share items must be necessary to the performance of the project.

2. In-Kind Cost Share - encompasses all contributions to the project made by the recipient or subrecipient(s) that do not involve a payment or reimbursement and represent donated items or services. In-Kind cost share items include volunteer personnel hours, donated existing equipment, donated existing supplies. The cash value and calculations thereof for all In-Kind cost share items must be justified and explained in the Cost Share section of the project Budget Justification. All cost share items must be necessary to the performance of the project. If questions exist, consult your DOE contact before filling out the In-Kind cost share section of the Budget Justification.

3. Funds from other federal sources MAY NOT be counted as cost share. This prohibition includes FFRDC subrecipients. Non-federal sources include any source not originally derived from federal funds. Cost sharing commitment letters from subrecipients must be provided with the original application.

4. Fee or profit, including foregone fee or profit, are not allowable as project costs (including cost share) under any resulting award. The project may only incur those costs that are allowable and allocable to the project (including cost share) as determined in accordance with the applicable cost principles prescribed in FAR Part 31 for For-Profit entities and 2 CFR Part 200 Subpart E - Cost Principles for all other non-federal entities.

DOE Financial Assistance Rules 2 CFR Part 200 as amended by 2 CFR Part 910

As stated above, the rules associated with what is allowable cost share are generally the same for all types of organizations. Following are the rules found to be common, but again, the specifics are contained in the regulations and cost principles specific to the type of entity:

(A) Acceptable contributions. All contributions, including cash contributions and third party in-kind contributions, must be accepted as part of the prime recipient's cost sharing if such contributions meet all of the following criteria:

(1) They are verifiable from the recipient's records.

(2) They are not included as contributions for any other federally-assisted project or program.

(3) They are necessary and reasonable for the proper and efficient accomplishment of project or program objectives.

(4) They are allowable under the cost principles applicable to the type of entity incurring the cost as follows:

a. For-profit organizations. Allowability of costs incurred by for-profit organizations and those nonprofit organizations listed in Attachment C to OMB Circular A–122 is determined in accordance with the for-profit cost principles in 48 CFR Part 31 in the FAR, except that patent prosecution costs are not allowable unless specifically authorized in the award document. (v) Commercial Organizations. FAR Subpart 31.2—Contracts with Commercial Organizations; and

b. Other types of organizations. For all other non-federal entities, allowability of costs is determined in accordance with 2 CFR Part 200 Subpart E.

(5) They are not paid by the federal government under another award unless authorized by federal statute to be used for cost sharing or matching.

(6) They are provided for in the approved budget.

(B) Valuing and documenting contributions

(1) Valuing recipient's property or services of recipient's employees. Values are established in accordance with the applicable cost principles, which mean that amounts chargeable to the project are determined on the basis of costs incurred. For real property or equipment used on the project, the cost principles authorize depreciation or use charges. The full value of the item may be applied when the item will be consumed in the performance of the award or fully depreciated by the end of

the award. In cases where the full value of a donated capital asset is to be applied as cost sharing or matching, that full value must be the lesser or the following:

a. The certified value of the remaining life of the property recorded in the recipient's accounting records at the time of donation; or

b. The current fair market value. If there is sufficient justification, the Contracting Officer may approve the use of the current fair market value of the donated property, even if it exceeds the certified value at the time of donation to the project. The Contracting Officer may accept the use of any reasonable basis for determining the fair market value of the property.

(2) Valuing services of others' employees. If an employer other than the recipient furnishes the services of an employee, those services are valued at the employee's regular rate of pay, provided these services are for the same skill level for which the employee is normally paid.

(3) Valuing volunteer services. Volunteer services furnished by professional and technical personnel, consultants, and other skilled and unskilled labor may be counted as cost sharing or matching if the service is an integral and necessary part of an approved project or program. Rates for volunteer services must be consistent with those paid for similar work in the recipient's organization. In those markets in which the required skills are not found in the recipient organization, rates must be consistent with those paid for similar work in the labor market in which the recipient competes for the kind of services involved. In either case, paid fringe benefits that are reasonable, allowable, and allocable may be included in the valuation.

(4) Valuing property donated by third parties.

a. Donated supplies may include such items as office supplies or laboratory supplies. Value assessed to donated supplies included in the cost sharing or matching share must be reasonable and must not exceed the fair market value of the property at the time of the donation.

b. Normally only depreciation or use charges for equipment and buildings may be applied. However, the fair rental charges for land and the full value of equipment or other capital assets may be allowed, when they will be consumed in the performance of the award or fully depreciated by the end of the award, provided that the Contracting Officer has approved the charges. When use charges are applied, values must be determined in accordance with the usual accounting policies of the recipient, with the following qualifications:

i. The value of donated space must not exceed the fair rental value of comparable space as established by an independent appraisal of

comparable space and facilities in a privately-owned building in the same locality.

ii. The value of loaned equipment must not exceed its fair rental value.

(5) Documentation. The following requirements pertain to the recipient's supporting records for in-kind contributions from third parties:

a. Volunteer services must be documented and, to the extent feasible, supported by the same methods used by the recipient for its own employees.

b. The basis for determining the valuation for personal services and property must be documented.

APPENDIX B – SAMPLE COST SHARE CALCULATION FOR BLENDED COST SHARE PERCENTAGE

The following example shows the math for calculating required cost share for a project with $2,000,000 in federal funds with four tasks requiring different non-federal cost share percentages:

Task	Proposed Federal Share	Federal Share %	Recipient Share %
Task 1 (R&D)	$1,000,000	80%	20%
Task 2 (R&D)	$500,000	80%	20%
Task 3 (Demonstration)	$400,000	50%	50%
Task 4 (Outreach)	$100,000	100%	0%

Federal share ($) divided by federal share (%) = Task Cost

Each task must be calculated individually as follows:

Task 1
$1,000,000 divided by 80% = $1,250,000 (Task 1 Cost)
Task 1 Cost minus federal share = Non-federal share
$1,250,000 - $1,000,000 = $250,000 (Non-federal share)

Task 2
$500,000 divided 80% = $625,000 (Task 2 Cost)
Task 2 Cost minus federal share = Non-federal share
$625,000 - $500,000 = $125,000 (Non-federal share)

Task 3
$400,000 / 50% = $800,000 (Task 3 Cost)
Task 3 Cost minus federal share = Non-federal share
$800,000 - $400,000 = $400,000 (Non-federal share)

Task 4
Federal share = $100,000
Non-federal cost share is not mandated for outreach = $0 (Non-federal share)

The calculation may then be completed as follows:

Tasks	$ Federal Share	% Federal Share	$ Non-Federal Share	% Non-Federal Share	Total Project Cost
Task 1	$1,000,000	80%	$250,000	20%	$1,250,000
Task 2	$500,000	80%	$125,000	20%	$625,000
Task 3	$400,000	50%	$400,000	50%	$800,000
Task 4	$100,000	100%	$0	0%	$100,000
Totals	$2,000,000		$775,000		$2,775,000

Blended Cost Share %
Non-federal share ($775,000) divided by Total Project Cost ($2,775,000) = 27.9% (non-federal)
Federal share ($2,000,000) divided by Total Project Cost ($2,775,000) = 72.1% (federal)

APPENDIX C – WAIVER REQUESTS AND APPROVAL PROCESSES: 1. FOREIGN ENTITY PARTICIPATION AS THE PRIME RECIPIENT; AND 2. PERFORMANCE OF WORK IN THE UNITED STATES (FOREIGN WORK WAIVER)

1. Waiver for Foreign Entity Participation as the Prime Recipient

As set forth in Section III.A.iii., all prime recipients receiving funding under this FOA must be incorporated (or otherwise formed) under the laws of a State or territory of the United States and have a physical location for business operations in the United States. To request a waiver of this requirement, an applicant must submit an explicit waiver request in the Full Application.

Overall, the applicant must demonstrate to the satisfaction of EERE that it would further the purposes of this FOA and is otherwise in the economic interests of the United States to have a foreign entity serve as the prime recipient. A request to waive the *Foreign Entity Participation as the prime recipient* requirement must include the following:

- Entity name;
- The rationale for proposing a foreign entity to serve as the prime recipient;
- Country of incorporation;
- A description of the project's anticipated contributions to the US economy;
- How the project will benefit U.S. research, development and manufacturing, including contributions to employment in the U.S. and growth in new markets and jobs in the U.S.;
- How the project will promote domestic American manufacturing of products and/or services;
- A description of how the foreign entity's participation as the prime recipient is essential to the project;
- A description of the likelihood of Intellectual Property (IP) being created from the work and the treatment of any such IP; and
- Countries where the work will be performed (Note: if any work is proposed to be conducted outside the U.S., the applicant must also complete a separate request for waiver of the Performance of Work in the United States requirement).

EERE may require additional information before considering the waiver request.

The applicant does not have the right to appeal EERE's decision concerning a waiver request.

2. Waiver for Performance of Work in the United States (Foreign Work Waiver)

As set forth in Section IV.L.iii., all work under EERE funding agreements must be performed in the United States. This requirement does not apply to the purchase of supplies and equipment, so a waiver is not required for foreign purchases of these items. However, the prime recipient should make every effort to purchase supplies and equipment within the United States. There may be limited circumstances where it is in the interest of the project to perform a portion of the work outside the United States. To seek a waiver of the Performance of Work in the United States requirement, the applicant must submit an explicit waiver request in the Full Application. A separate waiver request must be submitted for each entity proposing performance of work outside of the United States.

Overall, a waiver request must demonstrate to the satisfaction of EERE that it would further the purposes of this FOA and is otherwise in the economic interests of the United States to perform work outside of the United States. A request to waive the *Performance of Work in the United States* requirement must include the following:

- The rationale for performing the work outside the U.S. ("foreign work");
- A description of the work proposed to be performed outside the U.S.;
- An explanation as to how the foreign work is essential to the project;
- A description of the anticipated benefits to be realized by the proposed foreign work and the anticipated contributions to the US economy;
- The associated benefits to be realized and the contribution to the project from the foreign work;
- How the foreign work will benefit U.S. research, development and manufacturing, including contributions to employment in the U.S. and growth in new markets and jobs in the U.S.;
- How the foreign work will promote domestic American manufacturing of products and/or services;
- A description of the likelihood of Intellectual Property (IP) being created from the foreign work and the treatment of any such IP;
- The total estimated cost (DOE and recipient cost share) of the proposed foreign work;
- The countries in which the foreign work is proposed to be performed; and
- The name of the entity that would perform the foreign work.

EERE may require additional information before considering the waiver request.

The applicant does not have the right to appeal EERE's decision concerning a waiver request.

APPENDIX E – GLOSSARY

Applicant – The lead organization submitting an application under the FOA.

Continuation application – A non-competitive application for an additional budget period within a previously approved project period. At least ninety (90) days before the end of each budget period, the Recipient must submit to EERE its continuation application, which includes the following information:

i. A report on the Recipient's progress towards meeting the objectives of the project, including any significant findings, conclusions, or developments, and an estimate of any unobligated balances remaining at the end of the budget period. If the remaining unobligated balance is estimated to exceed 20 percent of the funds available for the budget period, explain why the excess funds have not been obligated and how they will be used in the next budget period.

ii. A detailed budget and supporting justification if there are changes to the negotiated budget, or a budget for the upcoming budget period was not approved at the time of award.

iii. A description of any planned changes from the negotiated Statement of Project Objectives and/or Milestone Summary Table.

Cooperative Research and Development Agreement (CRADA) – a contractual agreement between a national laboratory contractor and a private company or university to work together on research and development. For more information, see https://www.energy.gov/gc/downloads/doe-cooperative-research-and-development-agreements

Federally Funded Research and Development Centers (FFRDC) - FFRDCs are public-private partnerships which conduct research for the United States Government. A listing of FFRDCs can be found at http://www.nsf.gov/statistics/ffrdclist/.

Go/No-Go Decision Points: – A decision point at the end of a budget period that defines the overall objectives, milestones and deliverables to be achieved by the recipient in that budget period. As of a result of EERE's review, EERE may take one of the following actions: 1) authorize federal funding for the next budget period; 2) recommend redirection of work; 3) discontinue providing federal funding beyond the current budget period; or 4) place a hold on federal funding pending further supporting data.

Project – The entire scope of the cooperative agreement which is contained in the recipient's Statement of Project Objectives.

Recipient or "Prime Recipient" – A non-Federal entity that receives a Federal award directly from a Federal awarding agency to carry out an activity under a Federal program. The term recipient does not include subrecipients.

Subrecipient – A non-Federal entity that receives a subaward from a pass-through entity to carry out part of a Federal program; but does not include an individual that is a beneficiary of such program. A subrecipient may also be a recipient of other Federal awards directly from a Federal awarding agency. Also, a DOE/NNSA and non-DOE/NNSA FFRDC may be proposed as a subrecipient on another entity's application. See Section III.E.ii.

APPENDIX F – DEFINITION OF TECHNOLOGY READINESS LEVELS

TRL 1:	Basic principles observed and reported
TRL 2:	Technology concept and/or application formulated
TRL 3:	Analytical and experimental critical function and/or characteristic proof of concept
TRL 4:	Component and/or breadboard validation in a laboratory environment
TRL 5:	Component and/or breadboard validation in a relevant environment
TRL 6:	System/subsystem model or prototype demonstration in a relevant environment
TRL 7:	System prototype demonstration in an operational environment
TRL 8:	Actual system completed and qualified through test and demonstrated
TRL 9:	Actual system proven through successful mission operations

APPENDIX G – LIST OF ACRONYMS

COI	Conflict of Interest
DEC	Determination of Exceptional Circumstances
DER	Distributed Energy Resources
DMP	Data Management Plan
DOE	Department of Energy
DOI	Digital Object Identifier
EERE	Energy Efficiency and Renewable Energy
FAR	Federal Acquisition Regulation
FFATA	Federal Funding and Transparency Act of 2006
FOA	Funding Opportunity Announcement
FOIA	Freedom of Information Act
FFRDC	Federally Funded Research and Development Center
GAAP	Generally Accepted Accounting Principles
IPMP	Intellectual Property Management Plan
LCOE	Levelized Cost of Energy
LOI	Letter of Intent
MPIN	Marketing Partner Identification Number
MYPP	Multi-Year Program Plan
NDA	Non-Disclosure Acknowledgement
NEPA	National Environmental Policy Act
NNSA	National Nuclear Security Agency
OMB	Office of Management and Budget
OSTI	Office of Scientific and Technical Information
PII	Personal Identifiable Information
PI&I	Permitting, Inspection, and Interconnection
R&D	Research and Development
RFI	Request for Information
RFP	Request for Proposal
SAM	System for Award Management
SETO	Solar Energy Technologies Office
SOPO	Statement of Project Objectives
SPOC	Single Point of Contact
TIA	Technology Investment Agreement
TRL	Technology Readiness Level
UCC	Uniform Commercial Code
WBS	Work Breakdown Structure
WP	Work Proposal