U.S. Department of Energy (DOE)
Office of Energy Efficiency and Renewable Energy (EERE)

Solar Energy Technologies Office Fiscal Year 2020 Funding Program

Funding Opportunity Announcement (FOA) Number: DE-FOA-0002243
FOA Type: Modification 00003
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FOA Issue Date:	February 5, 2020
Submission Deadline for Mandatory Letter of Intent (LOI) for Topics 1-7:	March 9, 2020
Informational Webinars:	Webinar information will be available in EERE Exchange at https://eere-Exchange.energy.gov.
Submission Deadline for Concept Papers: • Topic Area 8 SIPS applicants DO NOT submit a Concept Paper.	March 16, 2020
Submission Deadline for Mandatory Letter of Intent (LOI) for Topic Area 8: Small Innovative Projects in Solar (SIPS)	April 9, 2020
Submission Deadline for Full Applications:	June 18, 2020
Submission Deadline for Topic Area 8 SIPS Applications:	June 18, 2020
Expected Submission Deadline for Replies to Reviewer Comments (Topic Areas 1-7 only):	July 29, 2020
Expected Date for EERE Selection Notifications:	Late October 2020
Expected Timeframe for Award Negotiations:	Late December 2020

- Applicants must submit a Letter of Intent (LOI) by 5:00 p.m. ET on the due date listed above to be eligible to submit a Topic Area 8 SIPS Application, and a Letter of Intent (LOI) and Concept Paper by 5:00 p.m. ET on the due date listed above for Topic Areas 1-7 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.

- Application Submission Note: The topic areas for this FOA have separate EERE Exchange entries to accommodate their different timelines and application requirements.
  - Applicants to Topic Areas 1, 3, 4, 5, 6, 7 will submit their application materials at the DE-FOA-0002243 FOA link: https://eere-exchange.energy.gov/Default.aspx#FoaIdc8e280d2-b7bf-4138-810b-cad9ba1541ac
  - Applicants to Topic Area 2: Integrated Thermal Energy STorage and Brayton Cycle (Integrated TESTBED) will submit their application materials at the DE-TA2-0002243 FOA link: https://eere-exchange.energy.gov/Default.aspx#FoaId9d6ec5e2-0080-446d-b52b-df2988138b0c
  - Applicants to Topic Area 8: Small Innovative Projects in Solar (SIPS) will submit their application materials at the DE-TA8-0002243 FOA link: https://eere-exchange.energy.gov/default.aspx#FoaId14079b45-f924-4ab9-b543-9283ee4ffade
- 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.

Modifications

All modifications to the FOA are highlighted in the body of the FOA. Changes from modification 0001 are highlighted in yellow. Changes from modification 0002 are highlighted in green. Changes from modification 0003 are highlighted in blue.

Mod. No.	Date	Description of Modification
00001	3/09/2020	Clarifies, in Topic 2, that additional, small scale testing may be proposed in support of the main testing campaign, on page 31; clarifies project documentation expected, especially around issues encountered in commissioning and testing, and their resolution, on page 36.
00002	04/08/2020	At EERE, we understand that due to the coronavirus outbreak, many of us have had to make adjustments to our business operations and practices in order to safeguard the health and safety of our communities. Due to the extraordinary circumstances in which we now find ourselves, EERE is issuing an extension of 4 weeks to submit full applications to DE-FOA-0002243. The due date for Full Applications and SIPs Applications for this FOA is now June 18, 2020. 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. Thank you, applicants, for your continued efforts during this uncertain time. We hope that you and your loved ones are well and we look forward to hearing from you.
00003	5/21/2020	Adds, to topics 3 (page 40) and 7 (page 79), language clarifying preference for open data policies and access in project submissions and provides informational resources for applicants to help them integrate those open data practices into their work. Additional evaluation criteria will judge applicantions on their sufficient explanation of how project-generated data will be made available to researchers and other stakeholders(page 131). Clarifies (on page 104) allowability of additional reference pages for SIPs applications.

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I. Funding Opportunity Description

A. Background and Context

i. Overview and Purpose

This funding opportunity announcement (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). SETO supports solar energy research and development (R&D) in three technology areas—photovoltaics (PV), concentrating solar-thermal power (CSP), and systems integration—with the goal of improving the affordability, reliability, and performance of solar technologies on the grid. This section describes the overall goals of the Solar Energy Technologies Office Fiscal Year 2020 (SETO 2020) funding program and the types of projects being solicited for funding support through this FOA.

The SETO 2020 funding program seeks to advance R&D of solar technologies that reduce the cost of solar, increase the competitiveness of American manufacturing and businesses, and improve the reliability of the grid. These projects will advance R&D in PV, CSP, and energy management technologies, while also working to improve cybersecurity, expand solar to new applications like agricultural solar, integrate solar and storage, and utilize artificial intelligence to address research challenges.

By nearly every measure, the past decade was transformative for the solar industry. In 2010, solar represented a tiny fraction of the country's electricity supply, with about 2.5 gigawatts (GW) of solar capacity.[1] It took five years for solar capacity to grow tenfold, to 25 GW, and approach 1% of the country's electricity supply. Now, as we near the end of the decade, solar provides about 2.5% of U.S. electricity,[2] with nearly 70 GW installed and more than 2 million solar energy systems.[3] In some states and regions, solar represents over 10% of annual electricity generation.[4] Instantaneous solar generation can reach a much higher level, nearly 50% in some cases.[5]

In the course of growing from 2.5 GW to 70 GW, the solar industry has employed hundreds of thousands of workers and supported more than 10,000 solar businesses.[6] This growth has been enabled by dramatic declines in cost, in addition to federal, state,

[1] Wood Mackenzie/SEIA Solar Market Insight Report.
[2] U.S. Energy Information Administration (EIA).
[3] Wood Mackenzie/SEIA Solar Market Insight Report.
[4] U.S. Energy Information Administration (EIA). In California, solar has reached 19%.
[5] For example, in March 2018, the California Independent System Operator (CAISO) saw an all-time peak percentage of demand served by solar: 49.95%. See https://www.greentechmedia.com/articles/read/california-sets-two-new-solar-records.
[6] The Solar Foundation. National Solar Jobs Census 2017.

and local policies and incentives. Since 2010, solar PV costs have declined 70% to 80%, and solar has become one of the most economical ways to add new electricity generation to the grid.[7]

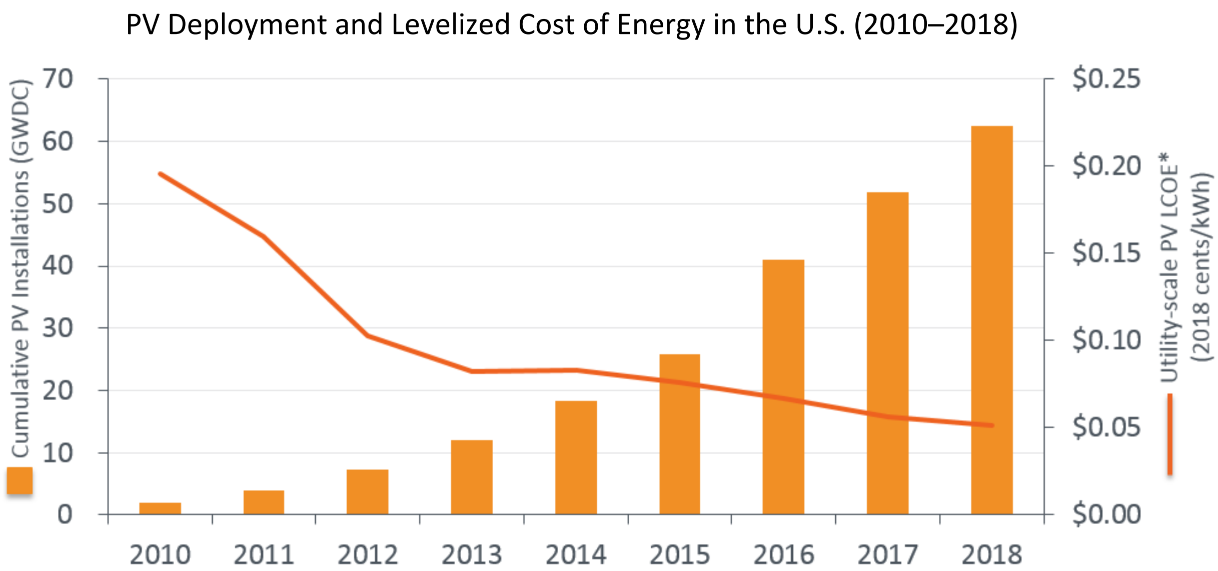

Figure 1. *The levelized cost of energy of utility-scale solar PV and cumulative deployment.[8] *Price is depicted as levelized cost of energy (LCOE).*

While this growth was largely concentrated in a few states—California, North Carolina, Arizona, Nevada, and Florida account for over 60% of the nation's installations—every state has seen solar industry growth. Since 2015, over 30% of new electricity capacity additions came from solar energy,[9] and solar is projected to account for 7% of all U.S. electricity by 2030 and 15% by 2050,[10] at current growth rates. If the price of solar electricity and/or energy storage decline faster than projected, that percentage could be much higher.[11]

[7] The average price per kilowatt-hour (kWh) of an unsubsidized utility-scale PV project has dropped from about $0.21 to $0.05. Data and methodology here: https://www.energy.gov/eere/solar/goals-solar-energy-technologies-office.

[8] National Renewable Energy Laboratory, *U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018*; GTM Research and SEIA, *U.S. Solar Market Insight Report: 2018 YIR.*

[9] U.S. Energy Information Administration. "Today in Energy." https://www.eia.gov/todayinenergy/detail.php?id=37952. January 10, 2019.

[10] U.S. Energy Information Administration. *International Energy Outlook 2019*. https://www.eia.gov/outlooks/ieo/pdf/ieo2019.pdf.

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

ii. Technology Space and Strategic Goals

American innovation and technology development pioneered the manufacturing and scale-up of solar PV technologies, beginning with the first solar manufacturing line built in 1979, in California.[12] U.S. R&D has helped lower manufacturing costs, increase efficiency and performance, and improve reliability of solar technologies. Over the past 35 years, SETO awardees achieved nearly half of all solar cell efficiency world records[13] and pioneered the development of molten salt in CSP plants, which is used as a blueprint for CSP plants around the world. The solar office currently supports nearly 400 solar projects across the country.

Since 2011, SETO has been working toward the SunShot 2020 cost goals to make solar electricity price-competitive with conventional utility sources.[14] Those investments have lowered costs across the solar value chain, enhancing business growth, and reducing red tape. National Laboratory test capabilities and research on degradation rates have supported longer lifetimes for PV systems, online tools have made it easier for consumers to determine if they can install solar and save money by doing so, and new racking systems have reduced installation times. The office has provided stakeholders the technical information they need to speed permitting and interconnection processes. These investments have helped secure American leadership in solar innovation and increase energy affordability across the country.[15]

In 2017, SETO announced that the industry had achieved the SunShot 2020 utility-scale cost goal of $0.03 per kilowatt-hour (kwh), three years early. Just as solar industry costs declined faster than what was considered ambitious in 2011, SETO expects that costs will continue to fall, as long as we maintain the pace of innovation. SETO has established new, more ambitious goals for 2030, which would cut the levelized cost of (solar) energy (LCOE) 50% between 2020 and 2030, while facilitating grid integration and opening new markets. Achieving these targets would make solar one of the most affordable sources of new electricity generation.[16] The targets for the unsubsidized LCOE at the point of grid connection[17] are:

- $0.03/kWh for utility-scale PV
- $0.04/kWh for commercial rooftop PV

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[12] ARCO Solar built the first manufacturing line in the U.S. in 1979.
[13] Based on SETO analysis of the National Renewable Energy Laboratory's efficiency chart.
[14] U.S. Department of Energy Solar Energy Technologies Office. *SunShot Vision Study*. 2012. https://www.energy.gov/sites/prod/files/2014/01/f7/47927.pdf.
[15] U.S. Department of Energy Solar Energy Technologies Office. "Connect the Dots: Innovations in Residential Solar." https://www.energy.gov/eere/solar/connect-dots-innovations-residential-solar
[16] U.S. Department of Energy. *The SunShot Initiative's 2030 Goal: 3¢ per Kilowatt Hour for Solar Electricity.* 2016. https://www.energy.gov/sites/prod/files/2016/12/f34/SunShot%202030%20Fact%20Sheet-12_16.pdf
[17] U.S. Department of Energy Solar Energy Technologies Office. "Goals of the Solar Energy Technologies Office." https://www.energy.gov/eere/solar/goals-solar-energy-technologies-office

- $0.05/kWh for residential rooftop PV
- $0.05/kWh for CSP with 12 or more hours of thermal energy storage

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

As a result of the recent progress in cost reduction and the rapid growth in solar deployment, the office has also expanded its focus beyond the exclusive challenges of cost to increase its work on how solar can support the reliability, resilience, and security of the grid. Today, solar only contributes energy to the grid—it doesn't help grid operators maintain system-wide balance or manage electricity transmission. SETO's research has laid the groundwork for solar to contribute to these essential grid reliability services. Over the next 10 years, the office will work to harness the capabilities of connected distributed energy resources to improve grid reliability. These devices will be able to contribute to power quality, match energy supply and demand, and restart power during an outage.

SETO Residential, Commercial and Utility Cost Goals

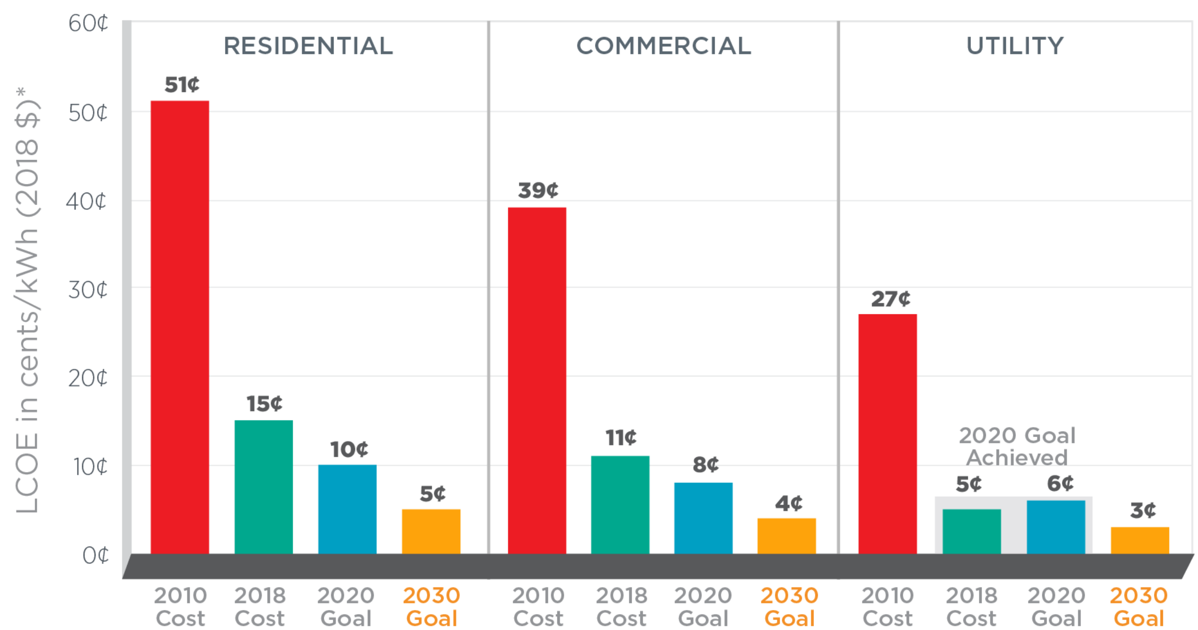

Figure 2. *2030 PV LCOE cost targets across the three solar market segments: residential, commercial, and utility-scale. The 2030 PV LCOE targets are calculated based on average U.S. climate and without the Investment Tax Credit. For example, a $0.03 LCOE for utility-scale would translate to $0.02 to $0.04 LCOE across the continental United States because of differences among locations in the amount of sunlight and in temperature, snow accumulation, and wind speed. The residential and commercial goals have been adjusted for inflation.*

In addition, the office has set a target for developing next-generation CSP power plants, which incorporate thermal energy storage to provide solar energy when the sun is not shining. These next-generation plants raise the temperature of the heat they deliver to the power cycle, thereby increasing the efficiency of the plant. The Generation 3 Concentrating Solar Power Systems[18] (Gen3 CSP) funding program, launched in 2018, provided $85 million for research to advance high-temperature components and develop integrated assembly designs with thermal energy storage that can reach operating temperatures greater than 700° Celsius (1,290° Fahrenheit). If successful, these projects will lower the cost of a CSP system by approximately $0.02/kWh, which is 40% of the way toward the office's 2030 cost goals of $0.05/kWh for baseload configurations.

SETO CSP Cost Goals

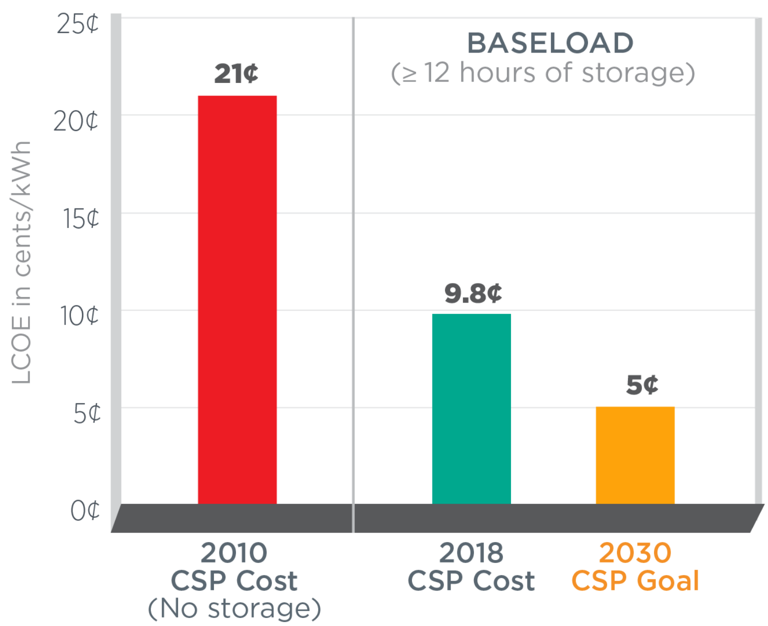

Figure 3. *2030 CSP LCOE cost targets for baseload power plants with 12 or more hours of storage*

Today, research must address the challenges solar faces as a more mature industry: integration onto the electric grid and with other energy technologies to support grid reliability and resilience, the need to continue to advance technologies to reduce costs and build a strong U.S. supply chain and manufacturing industry, cybersecurity, land-use competition, and non-hardware costs like permitting and financing as the energy landscape becomes more complex.

[18] U.S. Department of Energy Solar Energy Technologies Office. "Generation 3 Concentrating Solar Power Systems (Gen3 CSP). https://www.energy.gov/eere/solar/generation-3-concentrating-solar-power-systems-gen3-csp

The 2020s are expected to be a decade of strong solar growth, touching every state and expanding solar to new markets, like agricultural business and multi-family housing. These new areas will require additional research to tackle complex challenges, whether related to cost, technology, or permitting requirements. Agricultural solar applications, for example, may need totally different siting and installation practices than a typical utility-scale solar system. In addition, communities that want to use solar to increase their resilience may need new cost models than those that want to use solar only for energy production. In the same way, solar that can coordinate seamlessly with other technologies, like wind and storage, may have new technology challenges. The office will continue to provide objective information, pilot smart innovation, and develop and disseminate best practices to continue the growth of solar in more diverse and unique applications.

In addition, the office is working to support the growth of solar manufacturing in the United States. A forthcoming report from the National Renewable Energy Laboratory about domestic solar PV manufacturing expansions shows that the country's PV module capacity more than tripled in the past year.[19] While the growth in solar PV module manufacturing is encouraging, SETO is also working to expand the opportunities for manufacturing across the value chain—from manufacturing the capital equipment for making cells to developing the tools used in operations and maintenance (O&M). In last year's FOA, the office solicited hardware innovations, with a focus on developing technologies that will support a strong U.S. solar manufacturing sector and supply chain. SETO will continue to support these innovations, enabling the nation to keep pace with the rising domestic and global demand for solar energy products.

As the solar industry enters the next decade, SETO is working to integrate solar into the fabric of the American landscape—to help communities achieve their energy and resiliency goals, explore new applications of solar, drive innovation and entrepreneurship, and lower electricity costs.

iii. Cross-Office Coordination

SETO collaborates with other DOE offices. The Grid Modernization Initiative,[20] a program led by the Office of Electricity and other DOE offices to support the advanced grid of the future, is a key part of the solar office's grid integration efforts. These efforts are aligned

[19] The National Renewable Energy Laboratory. *Solar Photovoltaic (PV) Manufacturing Expansions in the United States, 2017-2019: Motives, Challenges, Opportunities, and Policy Context.*

[20] U.S. Department of Energy Grid Modernization Initiative. https://www.energy.gov/grid-modernization-initiative

with the technology areas in the Grid Modernization Multi-Year Program Plan,[21] including grid resilience, energy storage, sensors and measurements, and cybersecurity. In addition, SETO coordinates with the Office of Electricity to ensure that resilient solar will play a critical role in supporting U.S. Critical Infrastructure, including but not limited to the 16 sectors.[22] 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.

The solar office also collaborates with the Building Technologies Office, the Wind Energy Technologies Office, and other EERE offices 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. SETO works with the Offices of Nuclear Energy and Fossil Energy to advance research in the development of the supercritical carbon dioxide (sCO_2) Brayton cycle, as well as the Office of Fossil Energy's 10 megawatt-electric Supercritical Transformational Electric Power (STEP) pilot facility.

iv. 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 ambitious, high-impact research in the following areas:

Topic Area 1: Photovoltaics Hardware Research
This topic area seeks projects that will improve the functions of PV hardware over the long term, maximizing energy yields, increasing efficiency, and improving PV system modeling to ensure reliable performance prediction.

Topic Area 2: Integrated Thermal Energy Storage and Brayton Cycle Equipment Demonstration (Integrated TESTBED)
This topic area seeks to develop, build, and operate an sCO_2 power cycle integrated with thermal energy storage at temperatures in the range of 550°C to 630°C at a new or existing facility. The goal of this topic is to accelerate the commercialization of the sCO_2 Brayton cycle and provide operational experience for utilities, operators, and CSP developers.

Topic Area 3: Solar Energy Evolution and Diffusion Studies 3 (SEEDS 3)
This topic area will fund research programs that study how knowledge spreads throughout the solar energy ecosystem and how solar adoption interacts with other emerging energy technologies, such as energy storage. In particular, this

[21] U.S. Department of Energy Grid Modernization Multiyear Program Plan. https://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp
[22] U.S. Department of Homeland Security. https://www.cisa.gov/critical-infrastructure-sectors

topic will focus on understanding the large-scale dynamics of the flow of solar information. The goal is to reduce the non-hardware costs of solar energy by efficiently delivering knowledge to key stakeholders so that decisions can be made quickly and effectively in a rapidly changing energy landscape.

Topic Area 4: Innovations in Manufacturing: Hardware Incubator
This topic seeks to fund innovative product ideas that can advance solar energy technologies by lowering costs while facilitating the secure integration of solar electricity into the nation's energy grid. SETO has a particular interest in applications that develop impactful technologies that will support a strong U.S. solar manufacturing sector and supply chain. The goal of this topic is to de-risk new technologies, bring a prototype to a pre-commercial stage, and retire any business or market risks to spur follow-on private investments, patents, scientific and technical publications, and jobs.

Topic Area 5: Systems Integration
This topic area will enhance solar's ability to provide greater grid resilience and improved reliability to the nation's electricity grid, especially at the community level. This work will improve the ability of communities to maintain power during and restore power after man-made or natural disasters, improve cybersecurity for PV inverters and power systems, and develop advanced hybrid plants that operate collaboratively with other resources for improved reliability and resilience.

Topic Area 6: Solar and Agriculture: System Design, Value Frameworks, and Impacts Analysis
This topic area will build upon and expand ongoing SETO projects related to the co-location of solar and agriculture by developing technology, evaluating practices to date, and conducting research and analysis that enable farmers, ranchers, and other agricultural enterprises to gain value from solar technologies while maintaining availability of land for agricultural purposes. The goal is to facilitate and expand the co-location of solar and agricultural activities where it is beneficial to both industries and to the local community. For this topic, co-location is defined as agricultural production (i.e., crop or livestock production, or pollinator habitat) underneath solar panels and/or in adjacent zones around the solar panels.

Topic Area 7: Artificial Intelligence (AI) Applications in Solar Energy with Emphasis on Machine Learning
This topic area will leverage the substantial AI-related know-how developed in the United States. to develop disruptive solutions across the value chain of the solar industry. These projects will form partnerships between experts in AI and industry stakeholders such as solar power plant operators or owners, electric

utilities, PV module manufacturers, and others that can supply the necessary data as well as solar-related subject matter expertise.

Applicants that focus on machine learning or artificial intelligence related to microgrids, cybersecurity, or hybrid plants and grid forming should apply to Topic Area 5. Applicants with any other solar-related applications for artificial intelligence or machine learning should apply to Topic Area 7.

Topic Area 8: Small Innovative Projects in Solar (SIPS): PV and CSP
This topic area intends to fund innovative and novel ideas in PV and CSP that can produce significant results within the first year of performance. If successful, the outcomes will open up new avenues for continued study. Projects in this topic area are riskier than research ideas based on established technologies and will typically receive smaller amounts of funding than projects in other topic areas.

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.

This funding program is authorized under the Energy Policy Act of 2005, Section 931 (a)(2)(A) (42 USC 16231), which states that "The Secretary shall conduct a program of research, development, demonstration, and commercial application for solar energy, including— (i) photovoltaics; … (iii) concentrating solar power; … [and] (v) manufacturability of low cost, high quality solar systems...."

v. Teaming Partner List

Successful applications to many of the topics in this FOA will consist of research teams with partners across different industries and sectors. To facilitate the formation of teams, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List, which allows organizations that may wish to apply to the FOA but not as the prime applicant, to express interest to potential partners.

The Teaming Partner List and instructions will be available on EERE Exchange at https://eere-Exchange.energy.gov under FOA DE-FOA-0002243 during the FOA application period. The list will be updated at least weekly until the close of the full application period, to reflect new teaming partners who have provided their information.

Disclaimer: By submitting a request to be included on the Teaming Partner List, the requesting organization consents to the publication of its contact information. By enabling and publishing the Teaming Partner List, EERE is not endorsing, sponsoring, or otherwise evaluating the qualifications of the individuals and organizations that are identifying themselves for placement on this Teaming Partner List. EERE will not pay for the provision of any information, nor will it compensate any applicants or requesting organizations for the development of such information.

B. Topic Areas

i. Topic Area 1: Photovoltaics Hardware Research

Projects in this topic area will improve the functions of PV hardware over the long term, maximizing energy yields, increasing efficiency, and improving PV system modeling to ensure reliable performance prediction.

Background

The photovoltaics program works to reduce the levelized cost of energy (LCOE), to achieve the DOE cost goal of $0.03/kWh for utility-scale projects at U.S. locations with an average solar resource, and to enable even lower costs after achieving that goal. Achieving costs of $0.03/kWh would make solar one of the most affordable sources of new electricity generation,[23] help expand consumer choice, and increase options for energy resilience when coupled with energy storage. In 2017, DOE announced this target as a 2030 goal, but rapid innovation and scaling could enable reaching this target even sooner.

LCOE is the cost of electricity over the lifetime of the PV plant divided by the total energy output. It is decreased by reducing lifetime costs and/or increasing the energy produced over the operational lifetime of the system. One possible scenario for reaching $0.03/kWh is shown in Figure 4, below. Reducing the cost of the hardware and installation over the lifetime of the system are indicated by the red and yellow areas in Figure 4. Increasing the total energy output of a system over the plant lifetime is indicated by the green area.

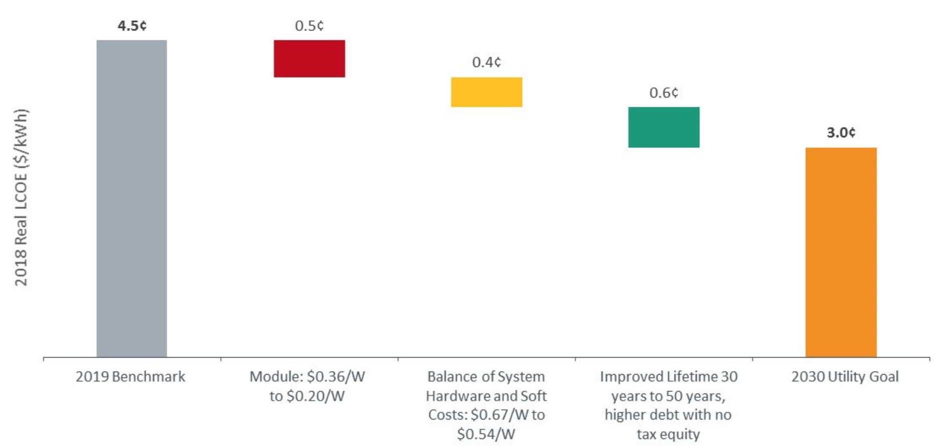

Figure 4. *Sample scenario for reducing costs to $0.03 per kWh for utility-scale systems*

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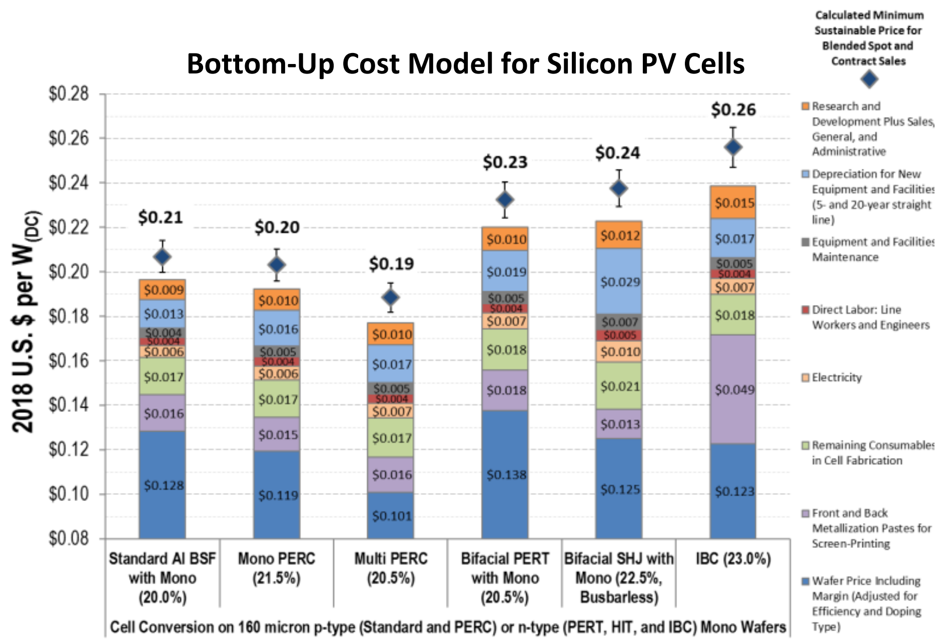
[23] U.S. Department of Energy. *The SunShot Initiative's 2030 Goal: 3¢ per Kilowatt Hour for Solar Electricity.* 2016. https://www.energy.gov/sites/prod/files/2016/12/f34/SunShot%202030%20Fact%20Sheet-12_16.pdf

There have been large price reductions for modules over the past decade, but further reductions (red area in Figure 4) are one critical piece of continuing to reduce costs. To achieve additional reductions, it is important to understand the biggest drivers, and the sensitivity of these drivers, in the cost of PV modules. The National Renewable Energy Laboratory estimated the 2018 manufacturing and materials cost for silicon modules, broken down for cells and modules, as shown in Figure 5. In that analysis, the estimated cost to manufacture cells was between $0.19/watt and $0.26/watt, and the module cost was between $0.37/watt and $0.41/watt, depending on the technology of the cell. This analysis shows that half the cost of silicon cell manufacturing can be attributed to the wafer price, and the three largest contributors are equipment and facilities depreciation, metallization materials costs, and consumables unrelated to metallization. For silicon module fabrication, almost half the costs are attributable to the non-cell bill of materials, such as the glass, encapsulant, backsheet, tabbing and stringing, and junction box. This analysis shows that lower equipment and materials costs of the module and system hardware can have a significant impact on LCOE.



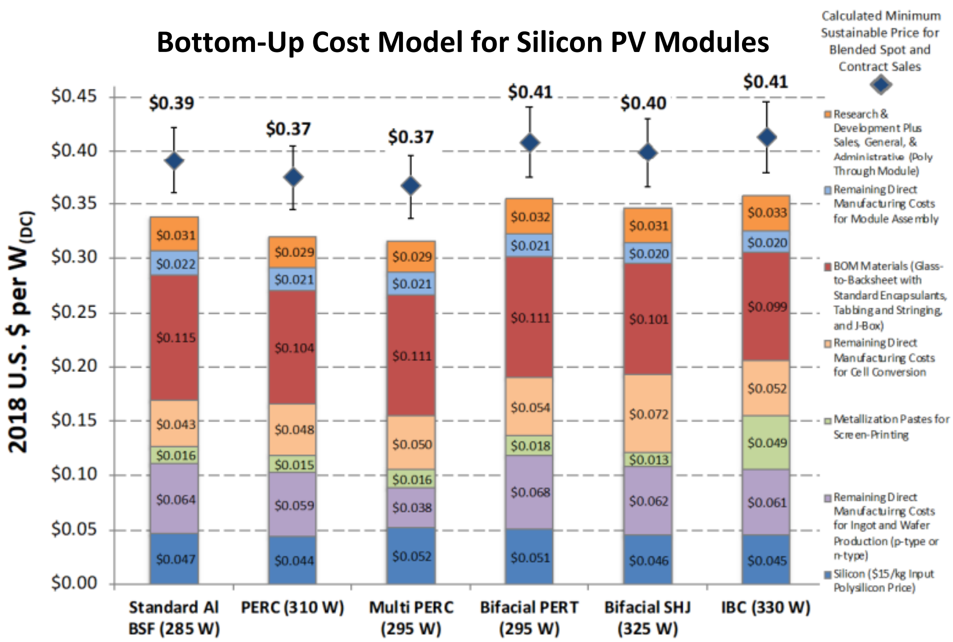


***Figure* 5.** Bottom-up cost models for various silicon cell (top) and module (bottom) technologies[24]

Novel or evolving technologies and manufacturing processes will have different cost breakdowns than these shown for silicon technologies, but any new technology will need to demonstrate costs that are competitive with incumbent technologies.

Hardware costs, measured in cost per watt, are also dependent on the efficiency of the technology, or the module's ability to convert sunlight into electricity. If efficiency can be increased while keeping total manufacturing costs the same through device performance improvements, this would reduce the cost per watt and similarly reduce the LCOE. Another variable that affects cost is the manufacturing production yield, which accounts for the number of rejected components or products during manufacturing. This is mostly controlled on the manufacturing side, but there may also be an opportunity to develop tools that allow consumers to test the performance of purchased products when received.

[24] National Renewable Energy Laboratory. *Crystalline Silicon Photovoltaic Module Manufacturing Costs and Sustainable Pricing: 1H 2018 Benchmark and Cost Reduction Road Map.* Woodhouse, Michael; et al. https://pdfs.semanticscholar.org/65cb/8369bdef088e89ff3c8ad7a1885ad57def5e.pdf

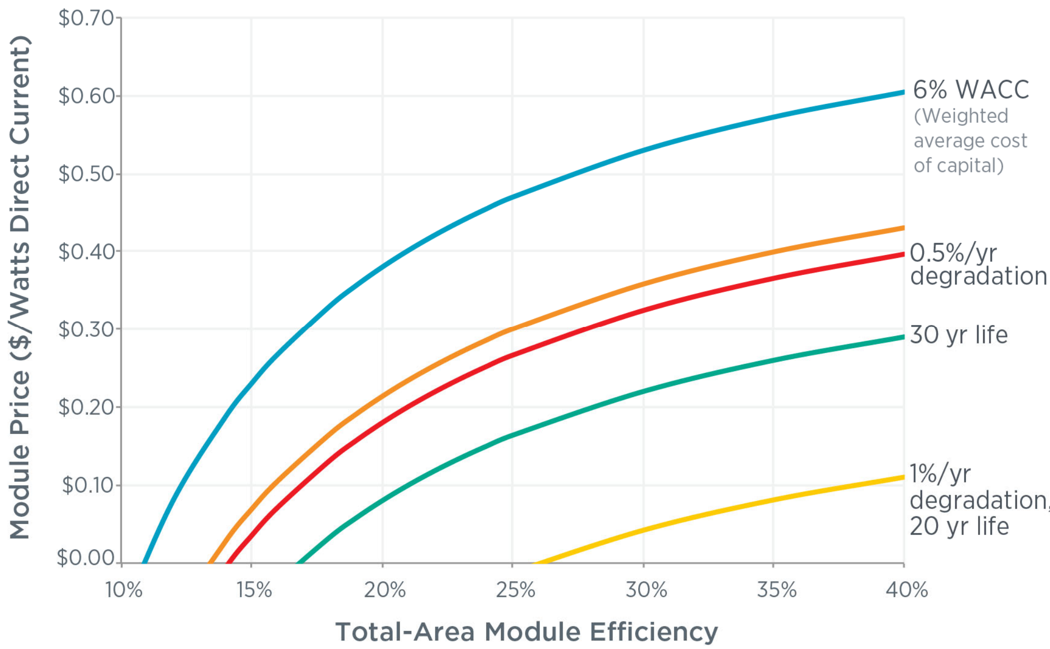


Figure 6. *LCOE curves showing combinations of module prices, module efficiency, degradation rate, and lifetime that will allow a system to reach $0.03/kWh. Unless otherwise noted, each line plots the maximum price and lowest efficiency to meet the $0.03/kWh target assuming a one-axis tracking system with 1,860 kWh (alternating current)/kW (direct current), a five-year modified accelerated cost recovery system, 7% WACC, 2.5% inflation, $4/kW-year O&M, 0.2%/year degradation, and a 50-year system lifetime.*

While many variables affect the total energy output of a system, three significant contributors are module efficiency, degradation rate, and total system operating lifetime. Figure 6 shows trade-offs that can be made to achieve $0.03/kWh. The orange and red curves show that raising the degradation rate from 0.2% (orange) to 0.5% (red) requires a reduction in module price of $0.02/watt to $0.05/watt or an increase in efficiency of 2% to 7% to reach the same LCOE target. The system lifetime has a similar effect—reducing the system lifetime from 50 years (orange curve) to 30 years (green curve) requires a reduction in module price by approximately half for a given efficiency.

Understanding a system's degradation rate and accurately predicting performance degradation over time are important for evaluating the total energy yield, which is the electricity output of a PV system over its lifetime. Issues that impact energy yield can range from material defects in the cell absorber—the semiconductor material that constitutes the core of a solar cell—to understanding the degradation and failure mechanisms of system-level components, such as bypass diodes, inverters, racking, trackers, and cables. Furthermore, identifying, understanding, and controlling the degradation mechanisms and rates in the system hardware can improve energy yield. More accurate models of energy yield can also affect the cost of the system by reducing the financing costs, because these models determine how panels and other system components meet expectations for output. Consistently meeting those expectations reduces financing risk for solar projects.

Evaluating the degradation rate of fielded hardware takes many years and requires many PV systems to reach statistically significant data. However, technologies change quickly, and reliability measured over multiple years before products are released is not always feasible. Therefore, the ability to better correlate accelerated tests with fielded performance is highly valuable and could accelerate the deployment of new advanced PV technologies.

Energy yield is also affected by the efficiency of modules and the design of the system as a whole. While there has been a lot of effective research at the cell level to increase efficiency, research efforts that include module and system considerations are important to maximize energy production. Understanding how to cost-effectively push energy yield higher for the final system will open up new paths to reducing LCOE.

To lower LCOE toward $0.02/kWh, hardware costs and energy yield need to be addressed simultaneously. Higher module efficiencies and new processes that may reduce cell conversion cost are generally competing factors that need to be optimized in parallel. Improving the understanding of energy yield of fielded modules is key, whether through studying and controlling defects, improving hardware reliability, or through improved tests and models to increase accuracy of energy yield projections.

SETO has made significant investments in improving efficiency, increasing energy yield, and extending lifetimes of solar cells and modules. The Foundational Program to Advance Cell Efficiency[25] programs in 2011 and 2013 focused on improving cell efficiency. The Physics of Reliability: Evaluating Design Insights for Component Technologies in Solar[26] programs in 2013 and 2015 focused on developing models to understand module-level degradation pathways both from a physics-based first-principles foundation and from phenomenological models. The Durable Module Materials (DuraMAT)[27] consortium was founded in 2017 to research degradation in module materials outside the cell. The PV topic area in SETO's FY2018[28] funding program solicited research collaborations to tackle bottlenecks in the development of certain PV technologies.

[25] U.S. Department of Energy Solar Energy Technologies Office. Round 1: https://www.energy.gov/eere/solar/solar-foundational-program-advance-cell-efficiency-round-1; Round 2: https://www.energy.gov/eere/solar/solar-foundational-program-advance-cell-efficiency-round-2.

[26] U.S. Department of Energy Solar Energy Technologies Office. Round 1: https://www.energy.gov/eere/solar/physics-reliability-evaluating-design-insights-component-technologies-solar; Round 2: https://www.energy.gov/eere/solar/physics-reliability-evaluating-design-insights-component-technologies-solar-2-predicts-2.

[27] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/durable-module-materials-consortium-duramat.

[28] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/seto-fy2018-photovoltaics.

While there are many areas to address regarding hardware costs and energy yield, the following have been identified as priority areas for this funding opportunity based on assessments of relevant literature and input provided to SETO. Projects responding to these priority areas should address the challenges and targets listed under each area.

Areas of Interest

To facilitate team formation, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List. SETO encourages applicants in this topic area to find potential partners on that list. Learn more in Section I.A.v.

Characterizing and Mitigating Performance Degrading Defects in Silicon PV

About 95% of solar panels on the market today use silicon as the semiconductor.[29] The best panels in use today have efficiencies of 18% to 22%, but efficiencies of modules coming off the line do not necessarily give a good prediction of lifetime performance in the field. Understanding how defects in silicon affect the performance of fielded operating modules could result in 1) better control of cell-related degradation mechanisms in manufacturing processes and 2) better performance in the field.

In silicon modules, defects or impurities in the silicon absorber layer affect module performance degradation. Some examples of silicon-related degradation in modules include bulk and interfacial defects that result in carrier recombination, carrier-induced degradation, and light-enhanced, thermal-induced degradation. While existing processing techniques can partially reverse these degradation pathways, the research community still lacks a fundamental understanding of the materials-level mechanisms behind the degradation.

Challenges in relating silicon defects to module performance include:

- Developing characterization capabilities that can identify silicon cell defects in the bulk and at interfaces that affect degradation
- Understanding how cell and module processing impacts defects in the absorber and at interfaces and, subsequently, the performance of modules
- Tracking defects in the field and correlating them to observed degradations

Projects in this area would quantify the impacts of defects on module performance for commercially relevant and upcoming silicon module technologies, and use this understanding to demonstrate processes that control defects and lower power degradation attributed to the absorber to less than 0.2% per year.

[29] The National Renewable Energy Laboratory. *The Role of Advancements in Solar Photovoltaic Efficiency, Reliability, and Costs.* Woodhouse, et. al. 2016. https://www.nrel.gov/docs/fy16osti/65872.pdf.

Characterizing and Mitigating Performance Degrading Defects in Cadmium Telluride (CdTe)

Thin-film solar cells make up approximately 3% to 5% of the global PV market. Structural, interfacial, and impurity-related bulk, interface, and surface defects in CdTe are understood to play a major role in limiting and/or degrading efficiency. There is a wide variety of such defects, and it is difficult to characterize and identify the underlying defect mechanisms in complete devices due to the low incidence rates, weak spectroscopic signals, and interference from other layers in the device. These challenges are some of the factors inhibiting increased widespread deployment of CdTe modules.

There has been significant work to identify and categorize the defects and structural deformations found in thin-film PV. Although many defects have been characterized and quantified, their exact impact and evolution during operation on device behavior is much less understood. In CdTe, for example, the impact of copper, grain boundaries, twin boundaries, impurity or structural point defects, and mobile elements have been extensively studied, but there is no final, clear consensus on their overall impact on device performance.

The main challenges for relating the defects to device and module degradation are:

- The difficulty in conclusively attributing the presence of a given impurity to observed device behavior
- The change in the behavior of a defect with the change in material composition, such as doping, alloying, or processing conditions
- The effect of grain boundaries on performance, including fabricating large grain materials at low cost
- Difficulties in identifying and tracking critical defects using most characterization techniques, given the number of impurities and the states they occupy
- The impact of processing conditions as well as testing conditions, like illumination level, humidity, temperature, and voltage bias, on observations and defect behavior and distribution
- The evolution of defects under real-life operating conditions in different locales
- The effect of the measurement itself changing the observed properties

Projects in this area will need theoretical and experimental approaches to conclusively relate specific defects in the bulk, at an interface, or the surface to device performance and degradation. The demonstration of high open-circuit voltage (V_{OC}) in single-crystal CdTe material, for example, makes it possible to study and compare devices with and without structural defects, like grain boundaries, or with and without specific elements, such as copper or chloride. Not only is it important to identify defects responsible for long-term degradation, but it is also crucial to have plans for effective defect mitigation, either through elimination, passivation, or limitation, in order to support and increase PV deployment of those technologies. Quantifiable performance metrics for this topic include: reducing overall metastability magnitude by half, limiting annual performance degradation to below 0.3%, and/or showing marked fill factor (FF) and V_{OC} improvements of V_{OC}*FF>0.8.

Correlation of Module-Accelerated Performance Testing with Field Performance

One of the biggest challenges the solar industry faces is accurately predicting how solar panels perform over their entire lifetime. This performance measurement helps the solar industry set accurate expectations for output.

Accelerated testing techniques use environmental chambers to take measurements with variable and controllable light intensity and temperature. These can be used to develop or confirm forecast models of energy yield or uncover early potential performance-loss rates that can have substantial financial impacts. Accurate models enable project developers to accurately predict the energy output of a system as a function of time, and therefore, predict the financial payout and economics of the investment. Predefined qualification stress tests and field-deployed module data of a few months or a couple of years are generally used to assess how solar installations will perform over 25 years. However, the current state-of-the-art accelerated testing does not allow for early detection of potential performance loss or sufficiently accurate energy yield predictions.

The main challenges are:

- Power performance data has considerable variation and background noise due to insolation and weather variations that obscure trends
- Available performance data does not sufficiently distinguish between the impacts of underperformance of other components of a PV system, like inverters or connectors
- There is a lack of high-quality, high-resolution performance and bill-of-materials data on PV modules (such as the encapsulant materials, backsheet material, junction box, cell production lot) and systems in different climates to enable correlation with accelerated testing
- There is little data on how extreme climate conditions change the performance of systems or result in system failure, and what types of changes or failures those may be
- More widespread module and string-level monitoring, sensing, and data collection is needed to generate fine-grained performance data, which could enable predictive models and improved testing
- There is insufficient understanding of the changes in device and material properties during accelerated testing under relevant environmental stressors, e.g., using environmental chambers with variable light intensity, temperature, and humidity controls that are integrated with reliable, high-resolution, in-situ measurement instrumentation

Numerical and theoretical models do not fully incorporate activation energies to enable comparison of accelerated test conditions with field conditions. Systematic analysis to extract degradation trends from the multiple parameter space of module and system data is lacking.

Projects in this area will examine the impact of accelerated testing on PV module materials, structure, and performance and correlate that with module performance in the field. Applicants are encouraged to make use of physics-informed module degradation models and field data to support and validate the understanding. These projects will develop advanced protocols for accelerated testing that reproduce field performance and will be validated on field performance data for approximately five years of operation time in field under different environmental conditions. Furthermore, SETO is interested in techniques and field-deployable instruments that help identify degradation and failure pathways and inform future accelerated data protocols that address a range of climate conditions.

Successful approaches should aim to show less than +/-0.1% power output deviation per year between accelerated testing prediction and actual module output, and identify the behavior of degradation-contributing factors.

Tandems Demonstrations at the String Level

One way to improve PV device efficiency is by using cells with two different semiconductors to make tandem solar cells. Tandem cells contain two semiconductor layers that absorb different parts of the solar spectrum, making better use of sunlight than single-junction cells do. As the efficiency of single-junction solar devices gets closer to theoretical maximums, it is harder to reduce LCOE with efficiency. Tandem devices are one way to continue to decrease LCOE through hardware efficiency advancements. However, as the LCOE curves in Figure 6 show, for each incremental increase in efficiency percentage point, the corresponding module cost-increase step gets smaller. Increasing the efficiency of a module from 20% to 30% allows for only a $0.10/watt increase in module cost. Therefore, a key challenge for tandems is increasing efficiency while keeping module costs low.

At the cell level, research groups have demonstrated tandems with impressive efficiencies, such as a monolithic two-terminal indium gallium phosphide/gallium arsenide cell at 32.8%, a mechanically stacked four-terminal gallium arsenide/silicon cell at 32.8%, and a monolithic two-terminal perovskite/silicon cell at 28%. However, demonstration of tandem devices has rarely gone past the cell level. In order for tandems to move to the module level, several challenges will need to be addressed, including:

- Developing designs to interconnect multiple cells to maximize energy yield;

- Developing low-cost power electronics to support module-level operation, if needed
- Optimizing the additional interlayers necessary for tandems at the cell and module levels for efficiency and reliability
- Understanding the impact of different performance and degradation rates of two types of absorbers in one package
- Developing new acceleration factors to understand degradation mechanisms for tandems that require different accelerated testing protocols and stability testing

Projects in this area will demonstrate one-sun tandem mini-modules of at least eight interconnected cells, a cell-to-module efficiency derate of less than 4% absolute, and a modeled module fabrication cost of less than $0.60/watt. Applicants must have established capabilities of producing tandem cell efficiencies greater than 25%. Proposed projects that focus on how to leverage U.S.-based manufacturing for tandem devices are also of interest.

Inverter and Module-Level Electronics Reliability

Non-photovoltaic electronic components can be found in almost every part of a PV system, whether they're modules, voltage optimizers, tracker controllers, or inverters. Their degradation or failure can have outsized negative impacts on system performance, so it is important to understand the reliability of these components in the field and how the components can be modeled. It's also important to develop methods to predict reliability using models, conduct accelerated life testing to understand component failure, and find ways to mitigate eventual failures. The mitigations may run the gamut from new designs to new manufacturing and testing processes, longevity certifications, and predictive monitoring.

The challenges in understanding the reliability of electronic components include:

- Most individual electronic components are not directly monitored by sensors
- If the electronic components were individually monitored, the data sets generated would be very large and difficult to analyze
- Modules and inverters undergo frequent redesign, which adversely impacts the generality of models and accelerated life testing

Projects in this area would produce the following:

- Multi-year collection of field-reliability data from electronic components commonly found in PV systems, with an overall outcome being the anonymization and public dissemination of the data when the project ends
- A physics-informed degradation model of electronic components commonly found in PV systems that is validated with accelerated life testing and field data

Advanced Stable Perovskite Cell Architectures and Interfaces

Perovskite solar cells are a type of thin-film cell named after the eponymous ABX_3 crystal structure and are built with layers of materials that are printed, coated, or vacuum-deposited onto a substrate. In the lab, perovskite solar cell efficiencies have improved faster than any other PV absorber material, from below 4% in 2009[30] to over 24% in 2019 at the research-cell scale.[31]

While the evolution of perovskite solar cells is a great accomplishment, this work has predominately focused on achieving record efficiencies, with stability and durability often being the second consideration. But to compete with incumbent PV technologies, perovskite cells have to become stable and durable enough to survive at least 20 years in outdoor conditions.

Researchers have demonstrated continuing improvements in stability for both encapsulated and bare devices under different acceleration conditions, but given the variability in devices, conditions, and evaluation criteria, it is difficult to directly compare these results. Multiple research groups have demonstrated perovskite devices that maintain 80% of the initial performance (T80) after 1,000 hours under continuous illumination. While this is a significant improvement over the very short device lifetimes initially reported, it is insufficient for field operations.

Some of the challenges to making a stable perovskite solar cell include:

- The tendency of perovskite absorbers to phase-segregate with illumination and degrade when exposed to modest heat and moisture
- Varying operating conditions used by different labs when measuring stability, and the variations in acceleration protocols for different cell structures/materials and their corresponding degradation pathways
- A slow feedback loop attributable to nascent measurement techniques for long-term performance of perovskite solar cells, which prevents optimizing for efficiency

Successful projects in this area will achieve aggressive encapsulated-cell lifetime goals, with an expected T80 greater than 20 years, and will maintain a performance floor of an initial efficiency greater than 18%. Applicants will need to justify their approach to estimating service lifetime using fielded deployment studies and/or published accelerated degradation protocols. Applicants must also consider the path to commercial viability and justify that the proposed structure can provide a cost-competitive PV technology.

Applications Specifically Not of Interest

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[30] The National Renewable Energy Laboratory. https://www.nrel.gov/pv/perovskite-solar-cells.html

[31] The National Renewable Energy Laboratory. https://www.nrel.gov/pv/assets/pdfs/best-research-cell-efficiencies.20190802.pdf.

Applications that do not sufficiently justify an expected cost reduction of the PV system based on the proposed technological improvement are not of interest.

ii. Topic Area 2: Integrated Thermal Energy STorage and Brayton Cycle Equipment Demonstration (Integrated TESTBED)

Application Submission Note: The topic areas for this FOA have separate EERE Exchange entries to accommodate their different application requirements.
Applicants to Topic Area 2: Integrated TESTBED will submit their application materials at the DE-TA2-0002243 FOA link: https://eere-exchange.energy.gov/Default.aspx#FoaId9d6ec5e2-0080-446d-b52b-df2988138b0c

This topic area seeks to develop, build, and operate an sCO_2 power cycle integrated with thermal energy storage at temperatures in the range of 550°C to 630°C at a new or existing facility (see Figure 7). The goal of this topic is to accelerate the commercialization of the sCO_2 Brayton cycle and provide operational experience for utilities, operators, and CSP developers.

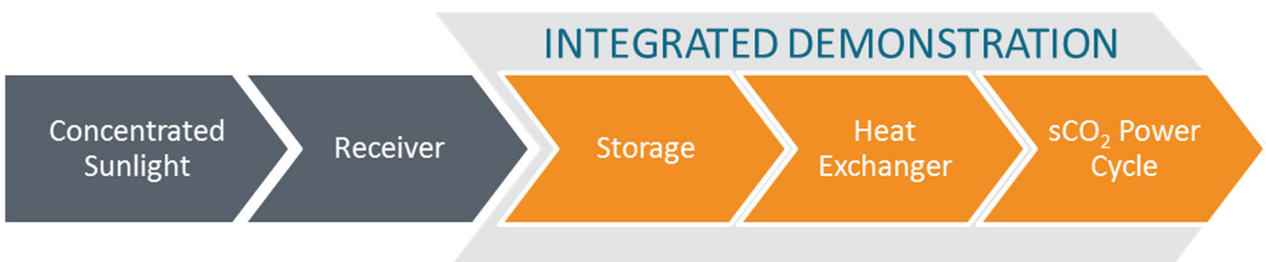

Figure 7. *An sCO_2 power cycle converts stored thermal energy into electricity. This topic area seeks projects that advance only the components in orange, under "Integrated Demonstration."*

Background

The SETO CSP program supports research, development, and demonstration projects 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 cost targets of $0.05/kWh for a baseload CSP plant with at least 12 hours of thermal energy storage (TES) and $0.10/kWh for a peaker CSP plant with a maximum of six hours of TES.

CSP systems capture the sun's energy in the form of heat, which can be stored and used to produce electricity even when the sun is not shining. The key 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 can provide reliable and flexible renewable electricity production. While there has been limited deployment of CSP, significant cost reductions must be realized to enable wide CSP deployment in the U.S.[32]

Achieving High Temperatures—Research and Development in CSP

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, and operate at a temperature of approximately 565°C, as shown in Figure 8. Recent SETO R&D objectives under the Gen3 CSP funding program[33] have focused on developing thermal transport systems capable of operating at temperatures greater than 700°C and integrating them with advanced, high-efficiency power cycles. Along with moving to higher temperatures, lowering solar field costs, and integration with high-efficiency, low-cost power cycles, there are other key elements of lowering the cost of energy generation from CSP. SETO is developing these concepts through projects awarded from the Gen3 CSP funding program. Additionally, the recent SETO Fiscal Year 2018[34] and Fiscal Year 2019[35] funding programs sought CSP projects that spanned a broad domain, touching every subsystem in the plant.

The efficiency of the power cycle directly affects the capital cost requirements of the entire CSP plant. Therefore, improving cycle efficiency is an important opportunity to reduce the cost of electricity from CSP—but these gains must not be offset by increased costs of materials. Typically, power cycle efficiency increases with the HTF's increasing operating temperature. Steam turbines, which are the power cycle used in most CSP plants, have a typical efficiency of 42%, because the thermal stability of the nitrate salt HTF limits the temperature to 565°C. However, the power cycle of a CSP tower plant is typically limited in size to less than 200 megawatts-electric (MW_e), due to the diminishing efficiency of a large heliostat array with distant mirrors. At this scale, a steam turbine is

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

[33] U.S. Department of Energy Solar Energy Technologies Office. FOA: https://www.energy.gov/eere/solar/funding-opportunity-announcement-generation-3-concentrating-solar-power-systems-gen3csp; Selections: https://www.energy.gov/eere/solar/generation-3-concentrating-solar-power-systems-gen3-csp

[34] U.S. Department of Energy Solar Energy Technologies Office. FOA: https://www.energy.gov/eere/solar/funding-opportunity-announcement-fy-2018-solar-energy-technologies-office; Selections: https://www.energy.gov/eere/solar/solar-energy-technologies-office-fiscal-year-2018-funding-program-seto-fy2018

[35] U.S. Department of Energy Solar Energy Technologies Office. FOA: https://www.energy.gov/eere/solar/funding-opportunity-announcement-solar-energy-technologies-office-fiscal-year-2019; Selections: https://www.energy.gov/eere/solar/solar-energy-technologies-office-fiscal-year-2019-funding-program-seto-fy2019

unlikely to achieve efficiencies above 50%, even if the plant achieves "ultra-super critical" temperatures and pressures.[36]

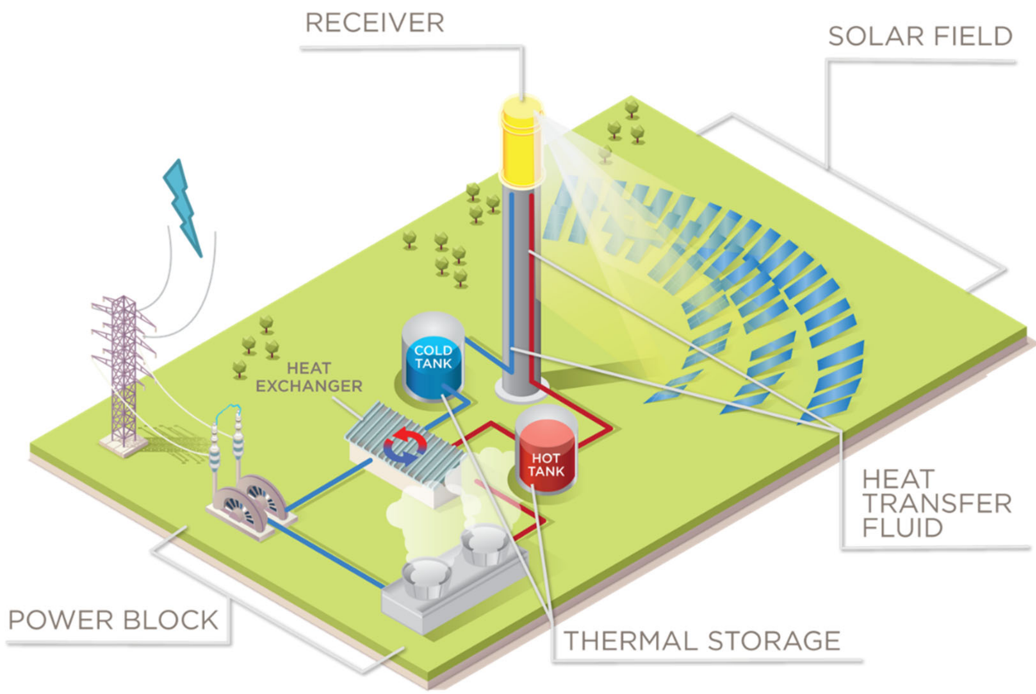

Figure 8. *Schematic showing the primary subsystems of CSP molten-salt-based plants*

In contrast, power cycles based on sCO_2 as a working fluid have been widely reported to be capable of meeting or exceeding 50% efficiency even at smaller capacities, potentially 20 MW_e or below. Turbines and heat exchangers for sCO_2 are predicted to have significantly lower capital costs than equivalent steam-cycle components because their footprint can be up to four times smaller than that of steam turbines. The nature of the sCO_2 Brayton cycle, which allows for sensible heat rejection in the precooler, as opposed to condensing steam at constant temperature in a Rankine cycle, is also highly favorable for dry cooling, so it can operate in environments that restrict water consumption.[37]

Supercritical Carbon Dioxide Power Cycles – Research and Challenges

While the SETO 2030 cost targets are agnostic to the specific thermal-to-electric power cycle used, the sCO_2 Brayton cycle is of particular interest to the office as a potential high-

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[36] Sandia National Laboratories. *Incorporating Supercritical Steam Turbines into Advanced Molten-Salt Power Tower Plants: Feasibility and Performance.* Pacheco, et. al. 2013. http://prod.sandia.gov/techlib/access-control.cgi/2013/131960.pdf.

[37] K. Brun, P. Friedman, and R. Dennis. *Fundamentals and Applications of Supercritical Carbon Dioxide (sCO_2) Based Power Cycles.* Woodhead Publishing, 2017.

efficiency, low-capital cost option. SETO and the DOE Offices of Nuclear Energy and Fossil Energy have collaboratively focused on the development of the sCO_2 Brayton cycle.[38] Shared research goals have accelerated the development of critical components and broadened the foundational knowledge related to this cycle.

Current DOE efforts, including the Gen3 CSP funding program and the Office of Fossil Energy's 10 MWe STEP pilot facility, are primarily focused on developing and de-risking components for cycles operating at a temperature above 700°C. These temperatures could potentially achieve net thermal-to-electric efficiencies of 50% or greater but push the limits of currently available materials for construction.

For utilities, operators, and CSP developers to adopt this novel power cycle, they need to operate the technology in more familiar settings, using lower temperatures and traditional steel piping and other components. Typical operational nitrate salt temperature is 565°C (1,050°F), which limits the sCO_2 cycle turbine inlet temperature to 550°C; but modern chrome-moly steels[39] have a limit of operation of 649°C (1,200°F), and stainless steels such as 347 (34700/34709) can also be used at these temperatures. Thus, operating in the 565°C to 649°C range will help utilities and operators feel comfortable relying on such cycles while they gain knowledge and experience that can enable transitioning to cycles at greater than 700°C.

Previous DOE-funded research was designed to develop and test components for an sCO_2 cycle operating in a **R**e**c**ompression **B**rayton **C**ycle (RCBC) configuration at the higher temperature of 715°C. Expanders[40] and compressors[41] have operated at the 1 MW_e scale, and installation and testing is in progress for an integrally geared compressor-expander[42] at similar temperatures. The Office of Fossil Energy's STEP pilot plant is the next step to advancing sCO_2 technology by going to a larger scale (10 MW_e). STEP objectives include refining the sCO_2 power cycle, demonstrating component performance and scalability, and designing the facility to accommodate multiple new supporting technologies.

To accelerate the commercialization of the sCO_2 Brayton cycle in a configuration compatible with CSP with TES, this topic area focuses on lower-temperature, nearer-term pathways for the technology. The temperatures of interest for the turbine inlet

[38] U.S. Department of Energy. https://energy.gov/under-secretary-science-and-energy/supercritical-co2-tech-team

[39] e.g., ASME B313 Code Case 2179-8 9Cr-2W P92.

[40] Southwest Research Institute. *Development of a High-Efficiency Hot Gas Turbo-expander and Low-Cost Heat Exchangers for Optimized CSP Supercritical CO_2 Operation.* J. Moore. 2019. https://www.osti.gov/biblio/1560368-development-high-efficiency-hot-gas-turbo-expander-low-cost-heat-exchangers-optimized-csp-supercritical-co2-operation

[41] U.S. Department of Energy Solar Energy Technologies Office. General Electric GE Global Research project profile. https://www.energy.gov/eere/solar/project-profile-general-electric-ge-global-research

[42] U.S. Department of Energy Solar Energy Technologies Office. Southwest Research Institute project profile. https://www.energy.gov/eere/solar/project-profile-southwest-research-institute

temperature of a sCO_2 power cycle heated from thermal energy storage range from 550°C to 630°C, integrated with thermal energy storage that operates in the temperature with a maximum temperature between 565°C and 650°C. The goal of the Integrated TESTBED topic is to derisk sCO_2 cycle operation in a commercial embodiment that avoids using nickel-based superalloys, which are in the early stages of industry adoption and therefore currently high-cost and have limited availability in manufacturing and fabrication suppliers.

Figure 9 shows the scope of the Integrated TESTBED topic. This topic solicits technologies in the power block and thermal energy storage subsystems but does not intend to develop innovations in the solar collector field, tower, or receiver.

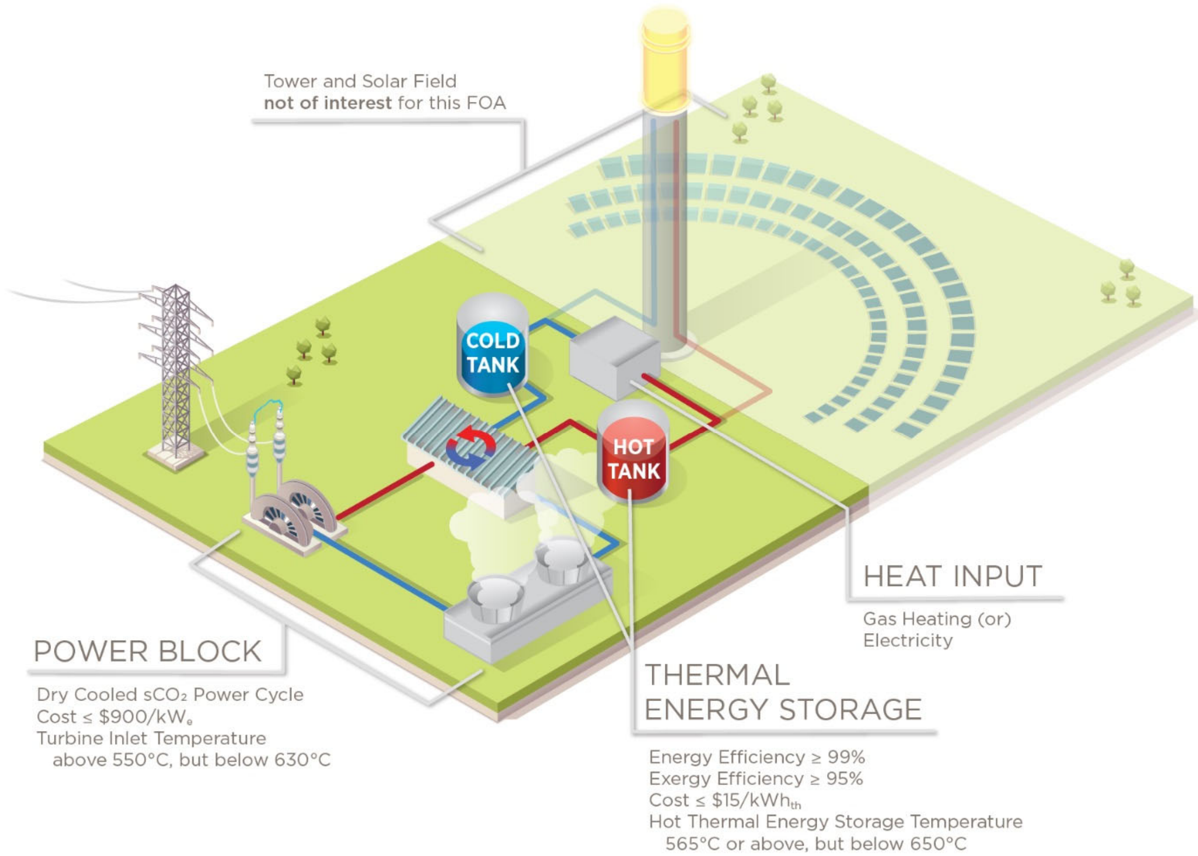

Figure 9. *Schematic showing the scope of the Integrated TESTBED topic, which solicits technologies in the power block and thermal energy storage subsystems*

Areas of Interest

Applications to this topic must address the following research challenges focused on the integration and operational flexibility of a CSP plant coupled with an sCO_2 power cycle:

- Storing energy using a sensible thermal energy storage material—a material that does not undergo a phase change in the storage process, like a conventional nitrate salt, or a novel material like solid particles—is a critical challenge because of the mismatch in the temperature change (ΔT) across the sCO_2 cycle (150°C for the RCBC configuration) and the typical ΔT between the hot and cold tanks (270°C). The energy density of thermal storage is determined by the amount of material stored, the heat capacity of the material, and the ΔT between the hot and cold temperatures of the stored material. Therefore, the smaller ΔT required for sCO_2 as opposed to typical steam cycles implies much more thermal energy storage material needed for the same amount of stored energy, requiring larger and costlier tanks.
- To minimize environmental impact, and since water has low availability in the typical arid environments in which CSP plants are located, dry cooling is a requirement. However, the ambient temperature variation, on both a daily and a seasonal basis, is large, and operation of sCO_2 compressors in conjunction with precoolers need to consider near-critical and transcritical operation. Integrated testing of air-cooled heat exchangers is necessary at realistic sizes and temperatures—for example, at greater than 10 MW_{th} heat rejection at ambient temperatures between -10°C and 45°C.
- Existing molten-salt-based tower CSP plants with steam cycles operating at 565°C achieve approximately 41% gross efficiency. To be competitive in the near term, sCO_2 power cycles need to operate at comparable efficiencies for consideration by CSP plant developers. To demonstrate commercial relevance, fully integrated turbomachinery components—specifically, compressors and expanders with generators, operating together with recuperators—are necessary to validate higher cycle efficiency and/or lower cost than steam cycles at the same turbine inlet temperature. In addition, compressor and expander performance and efficiency must be validated in various design and off-design conditions to be able to accurately predict annualized performance.
- The baseline RCBC cycle configuration requires four heat exchangers: high and low-temperature recuperators, a primary heat exchanger, and an air cooler. Heat exchanger operation and behavior during quickly changing, or transient, conditions is particularly uncertain. Especially since the smaller size of sCO_2 turbomachinery should allow for rapid startup and shutdown, the ability of equipment to quickly respond and allow for the plant to adjust power output as demand for electricity changes, known as “load following,” has not been demonstrated.

To better understand the outstanding research questions in developing a TES-integrated sCO_2 power cycle, SETO convened a workshop and issued a request for information (RFI)[43] to understand the specific gaps to be derisked. The identified gaps are summarized on the sCO_2 workshop website. [44]

In addition to the specific gaps identified for each component of the system, several subsystem interactions must be considered in integrated testing for a broad range of steady state and transient conditions. Subsystem interactions include TES to the primary heat exchanger, expander to the compressor, and precooler to the compressor, in addition to recuperator interactions with the power block.

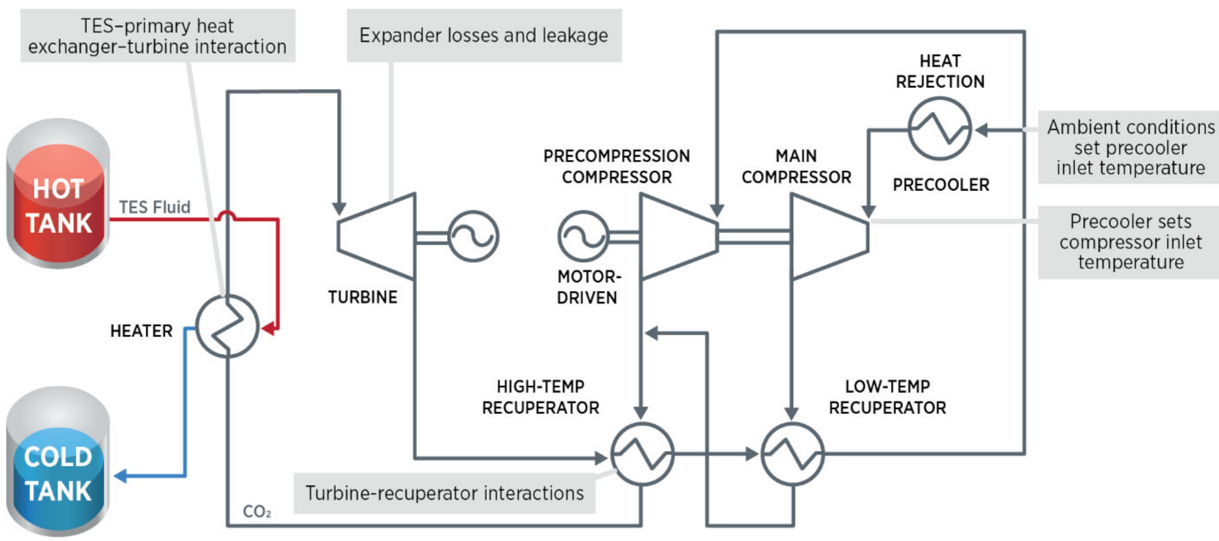

Figure 10. *Selected inter-component interactions that will be needed to be considered as part of TESTBED, using the RCBC cycle as an example*

Topic Area Goals and Performance Targets

A successful application in this topic will seek to develop, build, and operate a TES-powered sCO_2 cycle at a new or existing facility, with the intent of achieving the following performance targets:

- Develop and operate an sCO_2 cycle with a turbine inlet temperature between 550° and 630°C heated via thermal energy storage at a scale and over operating times sufficient to de-risk commercial operation. It is likely that at least 10 MW_e is required to test and evaluate turbomachinery design configurations and

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[43] U.S. Department of Energy Solar Energy Technologies Office. Supercritical Carbon Dioxide Power Cycles Integrated with Thermal Energy Storage. https://eere-exchange.energy.gov/#FoaIdff1b98e5-2d38-4943-9dfc-aa8fe9c5d85e

[44] U.S. Department of Energy Solar Energy Technologies Office. https://energy.gov/eere/solar/downloads/us-department-energy-sco2-workshop-2019

subcomponents that are relevant to utility-scale electric power generation. If a smaller size is proposed, the applicant should clearly justify and demonstrate that the selected size is scalable to utility applications and expectations of performance.

- Exercise specific turbomachinery operational risks, including integrated performance of dry gas and labyrinth seals, bearings, thermal management, thrust management with high-speed machines, operation of compressors with near critical CO_2, and integrated operation of compressors and expanders.
- Demonstrate the integrated performance of all the heat exchangers in an indirectly heated sCO_2 cycle, including the primary (TES-sCO_2) heater, high and low temperature recuperators, and air-cooled heat exchanger, with particular emphasis on transient, startup, and shutdown phases of heat exchangers.
- Develop experience for a broad range of cycle operation conditions and generate efficiency and performance maps for turbomachinery. For example, operation under various ambient and turbine inlet temperatures, full and partial power operation, load-following conditions, and startup.
- Develop control systems that can operate the power block with TES and air-cooled heat exchangers while maximizing operational autonomy and minimizing the need for on-site operators.
- Demonstrate the capability to monitor and characterize primary components or subsystems, like turbomachinery, heat exchangers, recuperators, bearings, and seals, under steady state, transient, and startup/shutdown conditions.
- Design, develop, and fabricate all components necessary for the power cycle, like turbomachinery, recuperators, and heat source integration, within the scope, cost, and schedule of the proposed test facility. For an existing facility, project proposals must specify which components will be new and which existing components will be used.
- Demonstrate the performance of individual cycle components and their ability to achieve performance consistent with an overall power cycle efficiency comparable with or better than the steam power cycle, at similar turbine inlet temperatures, both at the design point and on an annualized basis.
- Perform a testing campaign and data validation necessary to generate commercial confidence in operational standards for sCO_2 power blocks heated by indirect TES.
- Develop a dissemination plan to communicate the results and data to relevant stakeholders such that utilities, project developers, and financial institutions will be confident in building and operating sCO_2 power plants in the near future.

SETO is agnostic about the selection of a new or existing facility. Although a purpose-built facility has advantages in being able to design for specific testing needs, the cost of heat supply, heat sink, grid connection, and building facilities may make the proposed demonstration far more cost-effective at an existing facility. The following are required facility characteristics and activities in a successful testing program:

- The thermal energy storage capacity must be adequately sized to decouple the power block from the heat source. Sufficient thermal input to the system and TES such that the facility can provide operating characteristics that adequately emulate operating conditions found in a commercial CSP plant (e.g., transients, solar flux peaks, startup, ambient temperature ranges, part-load, load-following).
- The design, development, and fabrication of all equipment necessary for the integrated subsystems (e.g., thermal energy storage, salt pumps, lift systems for solid heat transfer media), heat source integration for thermal energy storage, and heat exchangers into the power cycle working fluid, compressors, expanders, precoolers, recuperators and other support systems for power cycle operation, such as lube oil and seal gas, must be included in the scope, cost, and schedule for the integrated test facility.
- The test facility must be designed to show a pathway to the SETO technology targets for the sCO_2 power block at a commercial CSP plant. That is, the facility <u>must be designed to give confidence in the successful operation of a full-scale, commercial power plant,</u> rather than representing a solution optimized at the smaller scale of the test facility.
- The test facility should enable the ability to investigate, study, and validate the performance of individual components within the integrated system, including the development of standard operating procedures. Testing should prove the ability of subsystems to achieve criteria consistent with the temperature, efficiency, and cost targets specified for Gen3 CSP. Critical components may include:
    - Turbomachinery and its subcomponents, including but not limited to bearings, dry gas seals, labyrinth seals, balance piston seals, thrust management systems, and thermal management
    - All heat exchangers, including recuperator(s), primary heat exchangers, and air-cooled heat exchangers, with careful consideration of transients
    - Standardized data acquisition and control, with an emphasis on operation by personnel equivalent to utility operators
    - Accessibility for maintenance or replacement of parts and subcomponents
    - Planned testing for a sufficient number of continuous operational hours and expected duty cycles to demonstrate reliable power cycle operation for long-term industry application
- The test facility must make validating component and material performance and degradation concerns possible, by obtaining relevant data within the integrated system at operating conditions.

- The proposal should clearly define the process test boundaries within the integrated facility with justification that the testing and resulting data quality will retire the most critical risks of the proposed system.
- The ability to adequately simulate the variations of ambient temperature for the dry cooler design.
- The disposition of the facility and its components after the conclusion of the proposed project should be described and costs accounted for.

While the above discussion focuses on the test facility and experiments in that facility, it may be appropriate to perform additional experimental campaigns elsewhere, in smaller scale facilities, on specific materials or sub-components. Similarly, sub-scale design and development validation may be required for components of the test facility. Applicants may propose relevant tasks, parallel to the test-facility, that will inform future commercial iterations of the developed technology.

Table 1 is a summary of specific performance metrics for subsystems and components developed toward a targeted commercial sCO_2 cycle. However, pathways relying on alternate cost or performance values that may enable a commercially successful design are welcome. The technical volume of the full application (see section IV.F, below) should specifically address either how the targets in Table 2 will be met or what success values will be pursued to meet the ultimate goal of this topic, and will be evaluated under Review Criterion 1 described in section V.A.ii. Details of test facility design, including construction, testing, and post-project disposition, should be addressed in the full technical application and will be evaluated under Review Criterion 2 described in section V.A.ii.

System / Component	Metric	Test Expectation	Stretch Goal	Clarifications
Power Cycle	Efficiency with inlet temperature≥ 550°C, %	>40	≥42	Target efficiency for testing program
	Capital Cost, $/kW	<900	<700	Plant capital cost for ≥50 MWe size
TES	Hot temperature, °C	565	650	Novel HTF and TES media will be needed to obtain temperatures above 565°C
Primary heat Exchanger	Effectiveness, %	90%		
	Approach temperature, °C	≤20	≤10	This describes the ΔT between TES and sCO_2
	ΔP, % inlet pressure	<1		
Expander	Efficiency, %	87	91	

	Expander Leakage, %	1	0.5	Leakage loss as a fraction of inlet flow
Compressor	Efficiency (and recompressor), %	82(82)	85(85)	
	Broad range performance	Provided by applicant		
Recuperators	Effectiveness, %	90%	92%	
	ΔP, % inlet pressure	<1		
	UA			
Air-Cooled Heat Exchanger	Effectiveness, %	90	92	
	Fan power, % cycle output	<1	0.5%	
	ΔP , % inlet pressure	<1		Optimum approach temperature to maximize efficiency
	Approach ΔT, °C	≤10	≤5	

Test Program Expectations				
Operation	Metric / Conditions	Program Minimum Targets	Program Stretch Targets	Clarifications
Design Point Operating Speed, Temperature, Pressure, and Mass Flow	Hours of operation at quasi-steady-state nominal design point conditions	≥1,000	≥2,000	Long duration tests are expected at the peak available power output at ambient conditions.
Cycles of Operation	Warm start / standby	≥250	≥500	
	Cold start / cold shutdown	≥10	≥20	
	Fast ramp start	≥20	≥50	Demonstrate best capability for fast start / ramp-up
	Soft trip stop	≥10	≥20	Controlled rapid shutdown (<2 minutes)
	Hard trip	≥5	≥10	Simulates expected disconnect from grid
Ambient Temperature Variation	Min	<10ºC		Steady-state operation at conditions where compressor inlet may be near or below critical point

	Max	>40 ºC		Cycle performance derate demonstrated at high ambient temperature
Dispatch Control (synchronous generator speed)	Ramp up and ramp down power output between full load and a part load minimum	<75% Part Load minimum 5% load / minute ramp rate Steady state load held within 0.5%	<25% Part load minimum 20% load / minute ramp rate	Dispatch control can be accomplished by several means: turbine inlet throttle, compressor speed, turbine inlet temperature, or system inventory

Table 1. *Performance targets for subsystems and components and test program targets*

Applicant Teaming Expectations

Under the Integrated TESTBED topic, SETO expects to award at least one multi-disciplinary, multi-organizational team to establish and lead a consortium of members committed to shared public/private investment in collaborative R&D focused on realizing a functional sCO_2 power block, powered by TES, in the near term in the United States. This team will initially provide a basic engineering, design, and cost estimate together with a budgetary proposal for meeting the requisite cost share (described below). To facilitate team formation, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List. Learn more in Section I.A.v.

Before receiving DOE approval to begin construction and large-scale procurement activity, the awardee(s) will be expected to propose a testing campaign and data validation plan to generate commercial confidence in operational standards for an sCO_2 power block heated by indirect TES. The consortium will:

- Lead a national team for the research, development, testing, verification, and validation of a near term sCO_2 cycle integrated with thermal energy storage
- Consist of or have substantial engagement with key industry members, including utilities, project developers, research organizations, turbomachinery and heat exchanger original equipment manufacturers (OEM), engineering, procurement and construction (EPC) companies, suppliers of subcomponents such as seals and control systems, and designers of thermal energy storage
- Develop a technology-transfer strategy by disseminating R&D results to facilitate commercial application of innovations
- Institute financial, legal, and governance structures to allow:
  - Maximization of research funds through industry matching of federal funds
  - Financial and contractual mechanisms to allow for collaboration across a wide variety of stakeholders for industrial benefit
  - A collaborative approach that enables prioritization of research needs through the consortium team to address technical challenges that will

have the highest impact in reducing the risk of sCO_2 power block development, operation, and testing in the near term
  - Rapid decision-making to address component and testing failure issues within the consortium
  - A consortium structure and initial membership that allows a basic engineering program and cost estimate to begin at the time of the EERE award

Cost share is required for all projects, but the cost share percentage may vary depending on the nature of the work in a task. A minimum 20% recipient cost share is required for R&D tasks; a minimum 50% recipient cost share is required for demonstration and commercial application tasks. Individual tasks will be cost-shared at either a 20% or 50% rate, depending on the type of work to be performed. (See Appendix B for more information on how to calculate cost share.) Generally, tasks that are focused on gaining a greater understanding of a process or technology—as well as the testing, refinement, and development of a prototype—are considered R&D. Tasks that consist of empirical or physical validation of technical feasibility and economic potential of a technology at a commercially relevant scale and realistic, non-simulated operating conditions are considered demonstration tasks. However, as each project is different, DOE will make a final determination as to the appropriate classification of each task.

To a large degree, the operation of the primary components and subsystems of a TES-integrated sCO_2 power cycle have been shown in either commercial operation with molten nitrate-salt-based TES or advanced R&D testing. Therefore, the bulk of the proposed tasks will most likely consist of demonstration activities, which require 50% cost share. Still, R&D activities may be necessary or beneficial to the program, especially in the initial stages, and may be budgeted as 20% awardee cost share. However, regardless of the focus of the tasks (R&D or demonstration) no more than 25% of the proposed budget may be cost shared at a recipient rate of 20%. At least 75% of the proposed budget must be cost shared at 50%.

SETO encourages applicants to classify each proposed activity as R&D or demonstration and identify the proposed budget and corresponding cost share for the type of work being proposed. One of the goals of this topic is to leverage non-federal funding to the maximum extent possible.

A successful application should include organizations with a variety of critical attributes. The following list describes key personnel that DOE expects. Depending on the specific team members, roles may shift over the course of the project, or multiple roles may be held by the same entity or co-investigator. The extent to which this topic's teaming expectation is met will be evaluated under Review Criterion 3 described in section V.A.ii.

DOE expects the project team to have the following participants:

- Principal investigator
  Responsible for the entire project, including cycle development, basic and detailed test facility design, and integrated testing; defining the concept system; directing or coordinating all critical activities and the generation, exchange, and evaluation of information throughout the program; working with the consortium to identify resources to address issues of failure and raising additional budgets in case of delays and equipment failures
- Technology champion
  Responsible for leading the commercialization of the technology through the development of operational standards and assuring that the cycle has been derisked and validated for near-term commercial sCO_2 applications
- Project management professionals
  Responsible for day-to-day management of the project, including schedule, budget and scope management
- Engineering, procurement, and construction professionals
  Responsible for developing design packages, procurement, construction, startup, and commissioning
- Subject matter experts in various subsystems and technical components
  Engineers with expertise in power cycle and thermal energy storage system components and subcomponents
- Materials scientists and manufacturing professionals
  Experts in metallurgy and manufacturing who can assist in the manufacturing and testing
- Business advisers
  Technology-to-market efforts for the anticipated near-term outcome of a commercial sCO_2 power cycle should begin at the start of the project. This will convey information to the general power industry, the finance community, and supply-chain vendors that support financed commercial sCO_2 power projects following the end of the proposed project.

Application Recommended Information

The general structure of the technical volume for the full application is described in Section IV.F.ii, below. In addition to the described requirements, applications to the Integrated TESTBED topic should include the following specific content within the technical volume:

1. Description and initial performance analysis of the proposed commercial sCO_2 power cycle, integrated with TES and dry cooling. Provide key assumptions, including but not limited to system boundary conditions, expected component costs, efficiency and parasitic loads, operating temperatures of key components, ambient air temperature in representative CSP environments, and an initial expectation of annualized power output for prescribed TES heat input.

2. Description of the planned methodology to resolve critical risks for the proposed integrated solution, including the identification and preliminary strategies to address subsystem development needs and how the test facility attributes and operational plan will be utilized. Additionally, the discussion should identify and analyze the strengths and weaknesses for alternate cycle designs and describe technology development risk mitigation strategies.
3. Description of the cost-effectiveness of the proposed facility design and technical approach in providing the best value of federal funds. For example, the trade-offs considered in terms of demonstration size versus industrially relevant experience gained, or using a greenfield facility versus existing facilities with already-purchased costly equipment. The discussion should include assumptions used in estimating the costs for design, engineering, construction, and operation of the integrated system.
4. To the extent possible, preliminary process diagrams and plans for the design, build, assembly, installation, permitting, and operation of the integrated test system. This should include the engineering design, which includes general layout of equipment and process flow diagrams, the approach to host site selection or integration with an existing site, the design of heat source to TES, the approach to heat rejection, the instrumentation and control requirements, the data acquisition requirements, all supporting balance of plant requirements, the test facility startup plans, and the facility operation plans.
5. Description of the appropriateness of planned location, including availability of space, existing infrastructure, utilities, personnel, and other capabilities. This should include details for available heat sources; identify compliance with applicable permit(s); limitations of site infrastructure availability, including electric power, fuel, water, accessibility, electrical grid connectivity, or on-site power dissipation; and highlight any additional service necessary to support a test facility. Compatibility of the demonstration at the proposed site with the conditions of the surrounding environment—and ability to meet any other appropriate environmental, health, safety, security, and permitting requirements including a National Environmental Policy Act (NEPA) review—should be addressed.
6. Description of a detailed test plan to address the topic objectives, including the collection and monitoring of test performance data and the generation and dissemination of information needed to adequately document achievements of the proposed project. Documentation of problems encountered during commissioning and testing, and their resolution, together with implications for further scaleup, must be maintained.
7. Description of the financial, legal, and project governance structures that the awardee's team will create to ensure broad industry engagement, rapid and flexible collaborative decision-making, and appropriate contractual mechanisms

and intellectual property management plans to perform the work with minimal administrative delays.

Applications Specifically Not of Interest
Applications will be deemed nonresponsive and declined without external merit review if they:

- Fall outside the technical parameters specified in Section I.B of the FOA, including but not limited to:
  - System designs that do not target a turbine inlet temperature of at least 500°C
  - Proposed sCO_2 cycles that do not incorporate thermal energy storage or do not use air-cooled heat sinks
- Propose technology innovation in solar collectors, receivers, and higher temperature (≥ 650°C) innovations in TES
- Propose technologies that are not based on sound scientific principles (e.g., violates the laws of thermodynamics)

iii. Topic Area 3: Solar Energy Evolution and Diffusion Studies 3 (SEEDS 3)

This topic area will fund research programs that study how knowledge spreads throughout the solar energy ecosystem and how solar adoption interacts with other emerging energy technologies, such as energy storage. In particular, this topic will focus on understanding the large-scale dynamics of the flow of solar information. The goal is to reduce the non-hardware costs of solar energy by efficiently delivering knowledge to key stakeholders so that decisions can be made quickly and effectively in a rapidly changing energy landscape.

Background

SETO's 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; building/construction and land permitting; contracts; capital costs; grid interconnection; independent audits and compliance with local codes, rules, and regulations; installation labor; and O&M. Soft costs can also take the form of indirect barriers to deployment that derive from factors including but not limited to local policy, overarching regulations, access to capital, and socioeconomic issues.

Although soft costs declined by 35% to 75% between 2010 and 2019 across residential-, commercial-, and utility-scale solar systems, hardware costs have declined even faster. As depicted below in Figure 141, this has resulted in an increasing share of softs costs relative to the total solar system cost.[45]

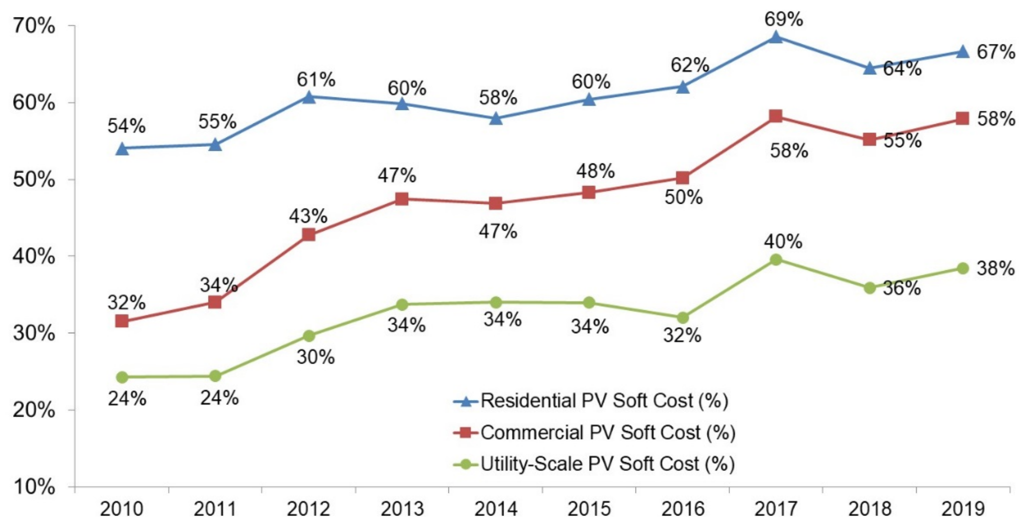

Figure 14. *Soft costs as a proportion of total up-front solar energy costs, by sector, 2010–2019*[46]

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, families, businesses, and manufacturers.[47] Lack of scientific and technical knowledge and lack of access to existing knowledge contribute to many soft costs. Understanding these knowledge barriers can unlock new opportunities to reduce soft costs.

SETO has funded programs that examined the mechanics and nature of the diffusion of solar energy, or how and why new technologies go mainstream. Solar Energy Evolution and Diffusion Studies (SEEDS), launched in 2013, focused on the ways in which solar technology was evolving, using data-driven case studies and analysis of publications, patents, and professional networks to create models of technological change and identify levers that could accelerate the improvement of solar energy technologies.[48] In addition, SEEDS examined the diffusion of technology through communities, by engaging in analysis and modeling of what makes market actors decide to adopt solar energy technology. SEEDS 2 was launched in 2016 and placed a focus on decision-making by

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[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 2019.* November 2019. Public link not yet available.

[47] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/soft-costs.

[48] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-energy-evolution-and-diffusion-studies-seeds

institutions and low-to-moderate-income consumers of solar energy.[49] This topic extends that body of work to focus on information flow and broader energy ecosystems.

Solar energy knowledge diffusion—the spread of solar energy knowledge to new individuals, institutions, and communities—relies on information being broadly available and easily accessible. As an example, the cost of a residential solar system has fallen to nearly one-third of its 2010 price on a per-watt basis,[45] but homeowners frequently do not realize how quickly the price has dropped and therefore don't know the true cost of a system.[50] Uncertainty and lack of knowledge contribute to longer decision-making times for purchasing solar,[51] and low-income individuals, who make decisions while facing greater financial stress,[52] may be disproportionately affected.

Private citizens rely on a variety of information sources to make solar purchase decisions, just as they do for other emerging products, such as electric vehicles.[53,54] Similarly, accurate and accessible information is key for decision makers, such as those in local governments or utilities, to connect new products to the grid. As new business models like community solar continue to grow, sharing new knowledge and best practices is particularly important.

Addressing these informational barriers is key to reducing the cost of solar. Research is needed on how institutions and communities absorb new information about solar energy and what types of connections and resources are most valuable to decision makers. Building on SETO's previous work, this topic will focus on the dynamics of the spread of solar information and how informational barriers can be overcome.

Another focus area in this topic is co-adoption of solar and other energy technologies, such as wind, energy storage, electric vehicles, energy efficiency, and industrial electrification. Institutions and individuals often do not make decisions about solar energy only—instead, they create multifaceted plans for their energy futures that encompass many different technologies. For example, in the SETO-funded Solar In Your Community Challenge,[55] a competition designed to incentivize the development of new approaches to increase the affordability of electricity, participants worked to implement energy-

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[49] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-energy-evolution-and-diffusion-studies-2-state-energy-strategies-seeds2-ses

[50] Rai, V. & Beck, A. L. *Environ. Res. Lett.* 10, 074011 (2015).

[51] Varun Rai and Scott A Robinson 2013 Environ. Res. Lett. 8 014044.

[52] Anandi Mani, Sendhil Mullainathan, Eldar Shafir, & Jiaying Zhao 2013, *Science,* Vol. 341, Issue 6149, pp. 976-980.

[53] Aspeteg, J. & Mignon, I. *J. Clean. Prod.* 214, 837–847 (2019).

[54] Taylor, M. & Fujita, K. S. LBNL--2001122, 1425436 (2018).

[55] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-your-community-challenge

efficiency measures alongside residential solar, which helped reduce the size and cost of systems installed.[56] Understanding these co-adoption trends and how they will impact the overall energy ecosystem is important for future research and planning needs.

Applicants should have a thorough plan for how their results will be published and disseminated to the most relevant stakeholders in the solar industry, as well as how project successes can be replicated in other areas. Applicants who rely on specific data sets for their analysis should be able to demonstrate that access to that data is feasible. All applicants must develop plans for data and protocol sharing with other projects funded under this topic and possibly with larger groups of researchers. Applicants are also encouraged to describe how they will adhere to FAIR guiding principles[57] for data access or why such adherence would not be feasible for their project. Examples of resources for best practices in open data policies can be found in the NSF DataOne program[58] or from the Center for Open Science.[59] For cross-disciplinary work, applicant teams should demonstrate a breadth of experience appropriate for the problem solved, including all relevant stakeholders or fields of technical expertise.

This topic area solicits project approaches inspired by community-based participatory research (CBPR), a framework developed in the fields of sociology and public health.[60] CBPR is a research model that promotes sharing the responsibilities and benefits of research with the community that hosts that research. By involving community organizations and other grassroots groups from the beginning of the research process, projects that build on the CBPR model allow local conditions to inform their analysis and provide active response to circumstances such as racial and economic inequality. Applications to this topic are not required to incorporate CBPR.

Teams with significant involvement from communities that are underrepresented in solar energy are especially encouraged to apply, as one goal of this topic is to identify informational barriers to equity and inclusion in renewable energy access. Such proposals should seek to address issues of community trust and historical context of energy development in the community, as well as any other relevant issues.

This topic will not provide funding for work related to federal, state, or local policymaking, including development of recommendations for policymakers.

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[56] Cook, J. J. *et al.* NREL/TP-6A20-72575, 1513199 (2019).

[57] FAIR stands for Findable (e.g. indexed in a searchable resource), Accessible (e.g. via an open protocol), Interoperable (e.g. including references to qualified data and metadata), Reusable (e.g. released with a clear and accessible data usage license). For a more detailed treatment please see https://www.go-fair.org/fair-principles/

[58] https://www.dataone.org/

[59] https://cos.io/

[60] Israel et al. *Annu. Rev. Public Health*. 1998. 19:173–202.

Topic Area 3.1: Strategic Knowledge Dissemination

This topic area seeks collaborative partnerships between entities that create knowledge products—such as journal articles, books, white papers, analyses, data sets, road maps, and strategic plans—and entities that use those products, including but not limited to community organizations, solar developers, trade associations, labor unions, state and local governments, utilities, and aggregators. These teams should explore and test mechanisms for disseminating solar knowledge so that it can be accessed, understood, and used by the maximum number of stakeholders possible. Teams should also examine how disseminating knowledge in these ways facilitates the evolution of solar technology and lowers costs and timeframes for solar energy deployment. Projects should attempt to quantify the effects of informational barriers on solar soft costs. To facilitate team formation, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List. SETO encourages applicants in this topic area to find potential partners on that list. Learn more in Section I.A.v.

Areas of Interest

Knowledge-Flow Mapping and Dissemination Plans
Projects should identify sectors of the solar energy market where knowledge flows can be mapped and categorized to understand how they can be improved. Projects should seek to define metrics or methods to optimize productive knowledge flows and identify bottlenecks or barriers. Examples include projects that identify new ways to make knowledge easier for users to find; studying the ways that new knowledge is integrated into planning processes; and scaling the practices of high-performing entities.

Knowledge Availability in Adjacent Fields
Projects should identify fields adjacent to solar energy, including but not limited to finance, construction, sustainability, and urban planning. Projects should include substantial participation from stakeholders in the tangential field(s). Solutions should identify barriers or gaps in solar information available to the field in question; quantify the effect of these gaps; and develop plans, recommendations, or best practices to address those gaps and make solar-relevant knowledge as accessible as possible.

Other Knowledge Projects
SETO welcomes applications that address other solar knowledge challenges, develop solutions that make knowledge more accessible to key stakeholders, and maximize the ability of the market and public sector to take advantage of cutting-edge academic and industry knowledge to reduce the costs and time lines for solar deployment.

Applications Specifically Not of Interest
Applications will be deemed nonresponsive and declined without external merit review if they:

- Focus on marketing research or sales techniques for solar technology
- Limit outputs to academic publications
- Focus on workforce training[61]

Topic Area 3.2: Leveraging Co-Adoption and System-Level Trends

This topic aims to unlock better understanding of co-adoption patterns, the behavioral impacts of co-adoption, and the value of combined systems. Projects must take a data-driven approach to examining how the evolution and diffusion of solar energy is influenced by the presence of other technologies. Projects can choose one specific technology as an intersection or take a broader perspective that combines several technologies.

Areas of Interest

Co-Adoption Trends and Mapping
Projects in this area will focus on the diffusion of solar energy and its correlation with other technologies, including but not limited to energy efficiency, electric vehicles, and energy storage. Projects should focus on how one energy technology helps or hinders the deployment of another, and mapping current co-adoption landscapes. Participants may also focus on how these trends interact with municipal, county, and state-level energy planning. Applicants should state in the application whether there is sufficient co-adoption of the technologies to form a statistically meaningful data set.

Co-Adoption Economics and Trends
Projects in this area should focus how the co-adoption of multiple technologies at once affect the behavior of end-users and the value of each technology. For example, the co-adoption of solar and other technologies may impact resilience planning and decision-making, and may change the quantity and timing of solar energy that is consumed on-site rather than exported to the grid, which could affect the overall value of the system in ways that cannot be traced to the individual technologies.

Other Co-Adoption Trends
SETO welcomes applications that investigate other co-adoption trends between solar and other technologies.

Applications Specifically Not of Interest
Applications will be deemed nonresponsive and declined without external merit review if they:

- Develop marketing strategies for energy services

[61] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-training-and-education-professionals-step

- Focus on technical co-adoption problems, like the development of a charge controller for a solar-plus-storage-plus-vehicle setup

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

This topic seeks to fund innovative product ideas that can advance solar energy technologies by lowering costs while facilitating the secure integration of solar electricity into the nation's energy grid. SETO has a particular interest in applications that develop impactful technologies that will support a strong U.S. solar manufacturing sector and supply chain. The goal of this topic is to de-risk new technologies, bring a prototype to a pre-commercial stage, and retire any business or market risks to spur follow-on private investment, patents, scientific and technical publications, and jobs.

Background

SETO's innovations in manufacturing competitiveness program supports the transformation of R&D results into products that can be manufactured in the United States. This program addresses key barriers to bringing a commercial solution to market. Addressing these barriers, which are currently too risky for the private sector to fund on its own, will allow companies to attract private-sector investment to bring the product to commercialization.

The manufacturing sector is vital to the U.S. economy, generating roughly 11.4% of U.S. gross domestic product (GDP)[62] and employing more than 12.8 million Americans.[63] DOE is committed to supporting U.S. manufacturing of solar energy technologies by funding early-stage R&D projects that result in new technologies to make solar energy more affordable, reliable, secure, and widely accessible.

America's innovators have an opportunity to develop new value streams and products that can penetrate domestic and global markets. DOE aims to support the U.S. in leading across the solar value chain—from manufacturing the capital equipment, packaging materials, and material components to making wafers, cells, and modules (also with new form factors) to developing O&M tools. One growing area of interest is power electronics. Power electronics devices, integrated with PV and storage controls, convert electricity from one form to another and deliver high-quality energy services wherever and whenever needed. Power electronics are accelerating technologies for solar grid

[62] Bureau of Economic Analysis. "Value Added by Private Industries: Manufacturing as a Percentage of GDP." Retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/VAPGDPMA, March 8, 2019.
[63] U.S. Bureau of Labor Statistics. "All Employees: Manufacturing." Retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/MANEMP, March 8, 2019.

integration and grid modernization, as 80% of electricity could flow through power electronics by 2030.[64]

SETO Commercialization Programs

SETO has supported the commercialization of solar innovations through funding programs that relate to one another but have their own unique attributes:[65]

- The American-Made Solar Prize[66] is a competition designed to support entrepreneurs as they develop transformative technology ideas into concepts and then into early-stage prototypes ready for industry testing. It is composed of three progressive phases over the course of a year, which are structured to provide the resources and environment necessary to create new solutions and develop them into early-stage prototypes. Along the way, competitors can receive prizes of up to $800,000 of a $3 million prize pool, based on performance at demonstration days and a streamlined review process.
- The Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) program[67] provides financial assistance in the form of grants to support early-stage R&D efforts at small businesses with a specific scope of work and clear objectives. It is a two-phase program, with the first phase focused on proving the feasibility of an idea (up to $200,000) and the second on prototype development (up to $1.1 million).
- Incubator FOAs or Incubator topics[68] in SETO-issued FOAs are restricted to for-profit entities and focused on moving innovative ideas from the proof-of-concept stage to market validation. Projects generally last one to three years, with federal funding up to $2 million and a 20% or 50% cost share requirement, depending on the funding opportunity. Financial assistance is in the form of cooperative agreements, which involve substantial federal oversight.
- The Technology Commercialization Fund[69] promotes federal R&D investments in technology with market potential where DOE National Laboratories are the lead applicants and require a commercial, private-sector partner to commit a 50% project cost share and be involved in project formation and execution. The goal

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[64] Oak Ridge National Laboratory. "Power Electronics for Distributed Energy Systems and Transmission and Distribution Applications: Assessing the Technical Needs for Utility Applications." Tolbert, L.M. https://www.osti.gov/biblio/885985

[65] Please read the relative funding opportunity announcement to learn more about eligibility criteria and cost share requirements of each program. Please note that these programs may or may not be announced, based on Congressional appropriation, programmatic decision, and office priorities.

[66] American-Made Challenges. https://americanmadechallenges.org/solarprize/index.html

[67] U.S. Department of Energy Solar Energy Technologies Office. https://energy.gov/solar-office/sbir

[68] U.S. Department of Energy Solar Energy Technologies Office. https://energy.gov/eere/solar/technology-market-competitive-awards

[69] U.S. Department of Energy Solar Energy Technologies Office. https://energy.gov/eere/solar/funding-opportunities

is to transfer the lab-developed technology to the commercial project partner. Federal funding is up to $750,000.

This Hardware Incubator topic is meant to support development of new technologies from a prototype to a pre-commercial stage. This topic is best suited for entities that have already developed their prototype and proved that the technology is feasible and provides advantages compared to the state of the art at a lab- or prototype-scale. However, these projects should still require federal funding to retire significant technical and business risks.

Organizations are strongly discouraged from submitting applications with similar scopes of work to multiple FOAs or multiple programs. EERE will provide funding only for a specific scope of work under one funding opportunity announcement or program. Applicants are responsible for choosing the proper funding opportunity or program for their proposed project. For help deciding where to submit your application, please see Figure 12.

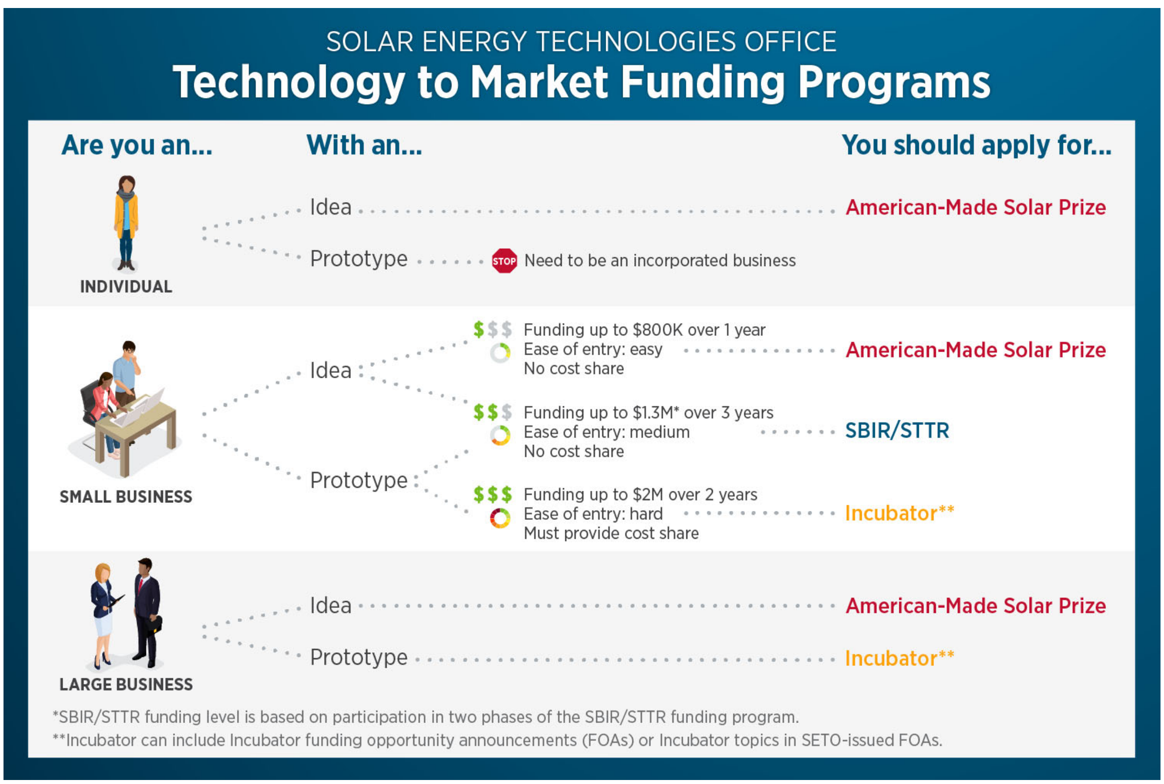

Figure 12. *SETO funding programs that support commercialization*

Areas of Interest

SETO seeks to fund solutions that can advance domestic manufacturing of solar energy technologies, including materials and tools to develop a robust domestic supply chain, while facilitating the secure integration into the nation's energy grid. Applications should fall within one of these areas:

- Advanced solar system integration technologies that enhance the ability of solar energy systems to contribute to grid reliability, resiliency, and security
- CSP and solar-thermal industrial process heat (SIPH)
- PV technologies

SETO encourages applicants to secure and leverage strong partnerships with established or adjacent industries that would speed up product development. To facilitate team formation, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List. SETO encourages applicants in this topic area to find potential partners on that list. Learn more in Section I.A.v.

This topic seeks to assist independent businesses that plan to identify a profitable, self-sustaining business opportunity based on their innovation. This topic is not soliciting the creation of a product, organization, service, or other entity or item that requires continued government support or that relies solely on a licensing model.

SETO is particularly interested in applicants that are developing:

- Improvements in assembly and installation efficiency, including methods to decrease direct installation cost (dollars/watt), decrease required installation time (minutes/watt), and/or increase supply-chain efficiency. Projects could leverage automation of various processes and tasks, up to and including full automation and robotic assistance, or combine low to high levels of automation with process improvements in traditional installation approaches. Proposals that address only logistical process improvements of traditional installation methods will not be considered.
- Integration of solar into the building envelope, including solar technologies that are fully integrated into windows, facades, or roofing materials. Applicants should demonstrate an improved *combined* value-to-cost ratio of the building envelope and generation system. Applicants may consider items such as innovative product designs, like form factors, and/or system designs for more complete roof and building envelope integration; innovative mounting and wiring or power transfer concepts; and solutions that address system aesthetics and/or customer acceptance or perception of solar installations.
- Novel PV panel manufacturing technologies—including module manufacturing methods that incorporate new cell technologies, such as perovskite or other high-efficiency solar cells—or reduce supply-chain capital expense.
- Technologies that can reduce the manufacturing costs of solar energy system components or subcomponents to boost domestic energy manufacturing and increase U.S. manufacturing competiveness.

- Technologies and components supporting current and future generations of CSP commercialization. Examples include developing heat exchangers and supporting systems to move energy from a CSP HTF to an sCO_2 power cycle at commercially relevant scales; relevant code case development or commercial acceptance case development for novel materials used for CSP heat exchangers, piping, thermal storage vessels, or receivers; advanced thermal energy storage systems de-risked in an environment and scale relevant to commercial operation. SETO targets thermal energy storage systems that cost less than $15/kW$_{th}$.
- Technologies and components supporting the development of SIPH, such as integrated concepts for collection, storage, and delivery of SIPH. SETO is interested both in low temperature applications (less than $.015/kW$_{th}$ at greater than 100°-400°C) and high temperature applications (less than $.03/kW$_{th}$ at greater than 600°C)
- Hardware technologies that reduce the balance of system costs of a PV system.

Application Guidelines

An ideal applicant for this topic would be an entrepreneur with an existing prototype that can demonstrate some functionality in a controlled environment. This award would enable the awardee to advance that prototype to become either commercially relevant or a minimum-viable product ready for pilot production. The research will seek to prove all functionality using pre-commercial assembly processes while also proving feasibility of any critical but high risk manufacturing steps. The application for the project should state how it will reduce the associated technical and business risks of the product. Due to the commercial nature of the projects, only for-profit entities and teams led by for-profit entities may apply.

A responsive application to this topic must:

- Include a summary of the milestones expected to be achieved by the end of the period of performance. Each application should include technical, business, and stakeholder engagement–related objectives with quantifiable, measurable, verifiable, and aggressive yet realistic success metrics and definitions of how completion of an objective will be assessed. Completion of a task or activity is not a milestone.
- Include projections for price and/or performance improvements that are referenced to a relevant benchmark
- Make an 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 competitively sustainable improvement
- Thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions

- Include a preliminary cost analysis that identifies assumptions and data showing a path to becoming cost-competitive with the evolving state of the art
- Justify all performance claims with theoretical predictions and/or relevant experimental data
- Describe how addressing the technical risks identified in the application will increase the likelihood of securing private investment following the award period
- Provide supporting documentation that validates the value proposition of the proposed solution
- Contain a thorough explanation of why federal funds are needed to develop the solution, why all proposed tasks warrant federal funding, why private-sector funding has been difficult to secure, and efforts by the applicant to date to secure private funding

Due to the commercial nature of the projects, funding is available only to teams led by for-profit entities.

Cost share is required for all projects, but the cost share percentage may vary depending on nature of the work in a task. A minimum 20% recipient cost share is required for R&D tasks; a minimum 50% recipient cost share is required for demonstration and commercial application tasks. Individual tasks will be cost-shared at either a 20% or 50% rate, depending on the type of work to be performed. (See Appendix B for more information on how to calculate cost share.) Generally, tasks that are focused on gaining a greater understanding of a process or technology—as well as the testing, refinement, and development of a prototype—are considered R&D. Tasks that consist of empirical or physical validation of technical feasibility and economic potential of a technology at a commercially relevant scale are considered demonstration tasks. However, as each project is different, DOE will make a final determination as to the appropriate classification of each task.

SETO encourages applicants to classify each activity as R&D or demonstration and identify the proposed budget and identify the corresponding cost share for the type of work being proposed. One of the goals of this topic is to leverage non-federal funding to the maximum extent possible. See Section V.C.i for the program policy factors that might be applied to determine which full applications SETO will select for award negotiations.

Applications Specifically Not of Interest

Applications will be considered nonresponsive and declined without external merit review if they:

- Do not have a significant hardware R&D effort
- Focus exclusively on HVAC or water heating applications
- Propose development of concentrated PV or solar spectrum splitting

- Propose development of racking and mounting of PV systems
- Propose technologies to improve the shade tolerance of PV modules
- Propose software-only solutions, including but not limited to software to facilitate system design or system monitoring and any software solution to improve customer acquisition processes. Hardware technologies that require also software innovation will be considered, as well as integrated hardware/software solutions.
- Are not based on sound scientific principles (e.g., violates the laws of thermodynamics)
- Discuss business plans or proofs-of-concept without including documentation supporting the necessity or benefit of the plan or concept. Competitive approaches in this application segment should be defined in the application.
- Propose to develop undifferentiated products, incremental advances or duplicative products
- Propose projects lacking substantial impact from federal funds. This topic intends to fund projects where federal funds will provide a measurable impact, (e.g., retiring risk sufficiently for follow-on investment or catalyzing development). Projects that have sufficient money and resources to be executed without federal funds are not of interest.
- Propose development of ideas or technologies that have already received federal support for similar technology at the same technology readiness level[70]
- Propose large-scale demonstration or deployment of solutions that do not require further R&D, unless field testing and early-stage pilots are part of the technology R&D cycle

v. Topic Area 5: Systems Integration

This topic area will enhance solar's ability to provide greater grid resilience and improved reliability to the nation's electricity grid, especially at a community level. This work will improve the ability of communities to maintain power during and restore power after man-made or natural disasters, improve cybersecurity for PV inverters and power systems, and develop advanced hybrid PV plants that operate collaboratively with other resources for improved reliability and resilience.

Background

The SETO 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. Increasing solar energy generation on the grid comes with technical, economic, and regulatory challenges, and it is necessary to develop

[70] U.S. Department of Energy Directives Program, Office of Management. https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04-admchg1

solutions that both ensure compatibility with the existing grid and enable a smooth transition to a secure, reliable, and resilient grid of the future. SETO is a part of the U.S. Department of Energy Grid Modernization Initiative, a crosscutting effort that aligns grid modernization efforts across multiple DOE program offices. SETO's systems integration research activities are aligned with the key technology areas identified in the Grid Modernization Multi-Year Program Plan.[71]

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. 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 enable the detection and mitigation of disturbances. Finally, it must provide strong protection against physical and cyber risks, including locating and utilizing solar to support critical defense infrastructure in the United States.[72]

A business-as-usual trajectory for the U.S. electric infrastructure will not result in a timely transition to a modernized grid. 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 deployment of distributed solar, like on homes and businesses, coincides with broader deployment of electric vehicles, more controllable building loads like programmable thermostats, and other smart generation, storage, and loads. Taken together, these devices represent distributed energy resources (DER).[73] Through automation, DER can provide improved comfort, health, and safety for their owners, and their controls can also be used by electric utilities to make the grid more reliable and affordable. While each DER provides relatively small generation compared to the large generators utilities historically controlled, when DER are controlled as a group—or aggregated—they can provide similar grid reliability and resiliency services. In some states, utilities can directly control DER; in other states, entities known as DER aggregators manage the group of devices, responding to price or other signals from the grid operator. Since DER and DER aggregators are so new, their impacts on the design and

[71] U.S. Department of Energy Grid Modernization Multiyear Program Plan. https://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp
[72] U.S. Department of Defense. https://policy.defense.gov/OUSDP-Offices/ASD-for-Homeland-Defense-Global-Security/Defense-Critical-Infrastructure-Program/
[73] North American Electric Reliability Corporation. *Distributed Energy Resources: Connection Modeling and Reliability Considerations.* 2017. https://www.nerc.com/comm/Other/essntlrlbltysrvcstskfrcDL/Distributed_Energy_Resources_Report.pdf

operation of the electric grid are not fully understood, so R&D is required to ensure they are integrated in an affordable, reliable, and secure manner.

SETO's prior systems integration research has laid the groundwork for using solar energy for greater grid resilience and improved reliability. Most recently, SETO released the Advanced SystemS Integration of Solar Technologies (ASSIST) funding program[74] in 2018, which focused on solutions that would enable grid operators to rapidly detect physical and cyber-based disturbances and use solar generation to recover quickly from power outages at critical infrastructure sites. This funding opportunity was followed by a topic in the Solar Energy Technologies Office Fiscal Year 2019 Funding Program,[75] which looked at how to provide 24/7 awareness of all systems on the grid, develop new technologies to detect disturbances, and develop tools and controls that can address those problems.

This FOA topic area will further enhance solar's ability to support resilience and reliability of the nation's electricity grid. The FOA will continue the office's work to advance grid operations technologies and enable solar to provide more grid services[76]—or enable grid operators to maintain system-wide balance and manage electricity transmission. These tools will examine not just solar but also the interaction between PV and other technologies, like wind, storage, or microgrids. In addition, it will advance the cybersecurity of solar technologies to better detect disturbances and develop strategies to survive a cyberattack.

Areas of Interest

As more solar generation is added to the grid, various challenges arise for grid planners at different operational time scales. However, integrating solar with other energy resources also provides opportunities to advance the grid into a more interactive, resilient, and flexible model. This topic area supports research in three areas to address these challenges and realize advancement opportunities: resilient community microgrids, cybersecurity, and hybrid plants.

Communities can make their energy supply more resilient by incorporating microgrid technologies with advanced controls for solar and DER. Microgrids[77] are localized electric

[74] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/advanced-systems-integration-solar-technologies-assist-situational-awareness-and

[75] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-energy-technologies-office-fiscal-year-2019-funding-program-seto-fy2019

[76] U.S. Department of Energy Solar Energy Technologies Office.https://www.energy.gov/eere/solar/solar-integration-inverters-and-grid-services-basics

[77] DOE defines a microgrid as ''a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island

grids that can disconnect from the traditional grid to operate autonomously. Because they can operate while the main grid is down, microgrids can strengthen grid resilience, help mitigate grid disturbances, and function as a grid resource for faster system response and recovery.

Given their smaller size and geographically broad dispersal, DER, including solar PV, present new cybersecurity vulnerabilities and challenges. Historically, solar's cyber risk was relatively minor, given the small percentage of our electricity supply provided by solar generation. Future solar inverters will require communication capabilities and grid-support functionality for abnormal electric grid conditions. As a result, the solar and DER industry must address the inherent cybersecurity vulnerability these devices present to the electric grid. As more solar is deployed, these devices must be securely integrated into DER aggregators[78] and utility controls.

Finally, large solar PV plants are starting to be built with energy storage or combined with other generation resources like wind or hydropower. Innovations in the design and operation of these hybrid plants can provide enhanced grid stability and grid services by operating as a single, highly flexible generating resource.

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

- **Topic Area 5.1: Resilient Community Microgrids** – Developing community-scale microgrids with high solar generation that can disconnect from the traditional grid to operate autonomously when the main grid is down.
- **Topic Area 5.2: Addressing Cybersecurity Gaps** – Developing solutions that proactively improve the cybersecurity of operational systems used by DER aggregators and electric utility operations for managing PV inverters and other DER.
- **Topic Area 5.3: Control and Coordination of a Hybrid PV Plant** – Developing design and control technologies that optimize single plants composed of solar, an additional generator, and/or storage to provide flexibility, stability, and grid-forming capabilities to the power grid.

To facilitate team formation, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List. SETO encourages applicants in these topic areas to find potential partners on that list. Learn more in Section I.A.v.

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mode." *The U.S. Department of Energy's Microgrid Initiative.* https://www.energy.gov/sites/prod/files/2016/06/f32/The%20US%20Department%20of%20Energy's%20Microgrid%20Initiative.pdf

[78] This article describes the emergence and role of DER aggregators: https://www.utilitydive.com/news/der-aggregation-sector-experts-identify-emerging-trends-in-a-nascent-marke/447670/

Projects that pursue demonstration must meet the cost-share requirements as described in Cost Sharing Section III.B. Projects pursuing demonstration are encouraged to work with critical infrastructure[79] owners and operators, industry, academia, and other stakeholders, including states, local government entities, tribes, and territories to use the demonstration to improve resiliency to critical national security assets, such as defense facilities and surrounding areas. Improvements would include sustainability following regional outages and rapid recovery following the outage.

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

Topic Area 5.1: Resilient Community Microgrids

This topic supports R&D, including demonstration, of resilient community microgrids to significantly improve electric reliability under normal operating conditions and maintain power during grid outages.[80] “Resilient community microgrids” as defined in this FOA are microgrids on a feeder scale with a high penetration of solar power (i.e., at least 75% of peak load) that provide power to one or more critical service facilities, like fire stations or hospitals (see Table 2). These grids could be a means of minimizing the societal and financial impacts of power outages associated with emergencies, natural disasters, and other unexpected events, while offering benefits to the communities during normal operations.

Distribution grids are vulnerable to outages that can impact large regions and millions of people and businesses, particularly as a consequence of extreme, destructive weather events. Over the past two decades, U.S. power outages have increased in size and frequency.[81,82] Community-scale microgrids could help minimize the impact of these outages by localizing power generation, distribution, and consumption so that a fallen tree, downed wire, and interruptions from the bulk power grid will not interrupt critical services.

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[79] Critical infrastructure means systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination thereof. (42 USC 5195c(e))
[80] “Lessons Learned From California’s Pioneering Microgrids.” Justin Gerdes. May 13, 2019. https://www.greentechmedia.com/articles/read/lessons-learned-from-californias-pioneering-microgrids
[81] “Impact of Power System Blackouts,” M. M. Adibi, and Nelson Martins, PowerPoint Presentation at 2015 IEEE Power & Energy Society General Meeting.
[82] “Leveraging Distributed Resources to Improve Resilience,” R. Arghandeh, M. Brown, A. Del Rosso, G. Ghatikar, E. Stewart, A. Vojdani, and A. von Meier, *IEEE Power & Energy Magazine*, September/October 2014.

Resilient community microgrids will require coordination with the bulk power system, the substation that takes the electricity from the bulk system, the feeders that distribute the electricity from the substation, and other microgrids that may be operating on the same distribution network. Figure 13 shows different scales of microgrids that could interact on the grid. A resilient community microgrid may consist of a full feeder microgrid or a network of partial-feeder and single-customer microgrids that are connected at multiple points and could be reorganized in a synchronized manner, allowing new microgrid connections to be made prior to breaking older connections.

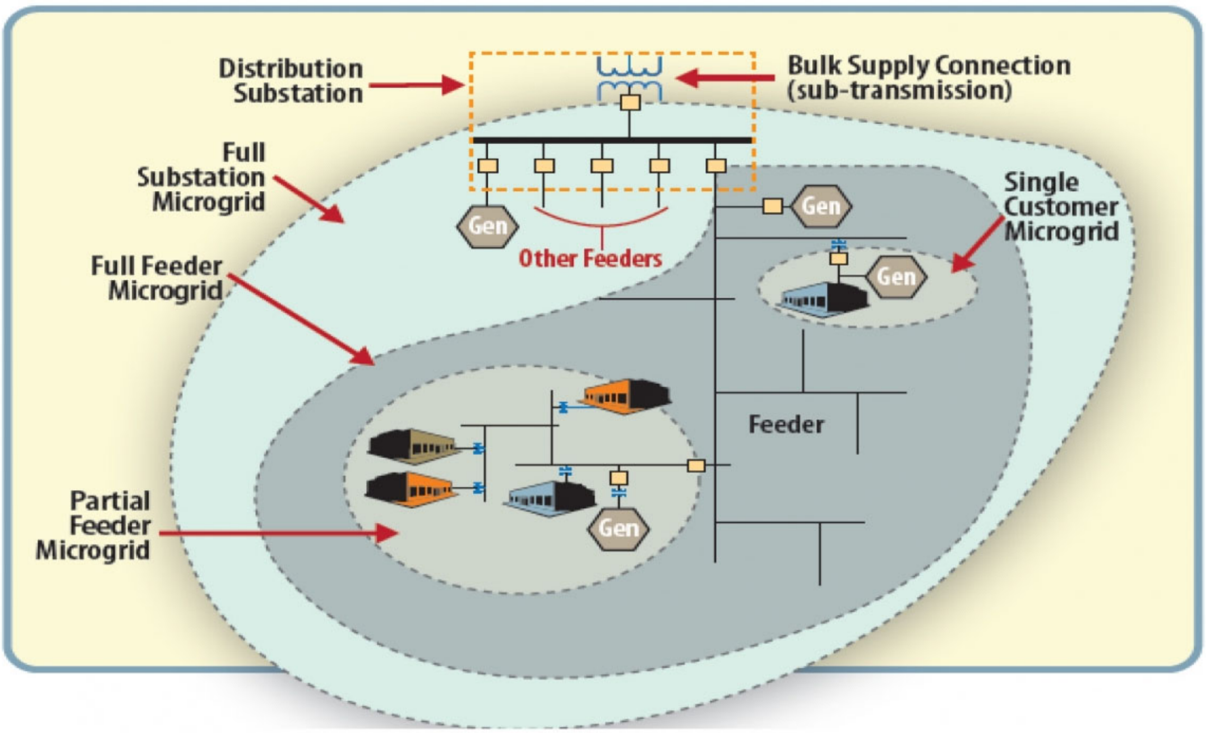

Figure 13: *Interconnected grids. Source: Electric Power Research Institute*

Achieving the goals of this topic requires the participation of community leaders and private and public sector participants. These projects will work to harden critical infrastructure, protect populations, and enable locally distributed energy resources to serve diverse communities and provide them tools for building a more reliable energy system.

Research Background and State of the Art

SETO and other DOE offices have funded several projects that contain the beginnings of the basic elements of resilient community microgrids. The Sustainable and Holistic

Integration of Energy Storage and Solar PV (SHINES) program[83] developed several methods to coordinate the use of smart inverters, battery storage, and controllable loads to meet customers' needs. Enabling Extreme Real-Time Grid Integration of Solar Energy (ENERGISE) projects[84] have focused on distribution planning and real-time operations tools to allow for dynamic automated management of DER at larger scales of penetration. The Grid Modernization Laboratory Consortium (GMLC) Resilient Distribution Systems (RDS) Lab Call projects, which are focused on enhancing the resilience of microgrids and other distribution systems with high penetration of DER have also developed initial frameworks and demonstrations of resilient grids and microgrids.[85]

The current state of the art utilizes spinning generation, like diesel and natural gas plants, to provide voltage and frequency control on the microgrid, with power supplemented by DER. When that microgrid is separated from the bulk grid in islanded or resilience mode, there will be fewer spinning generators available to provide a stable voltage and frequency on the grid.[86] Advanced "grid-forming" inverters in a microgrid with high PV penetration have the potential to establish frequency, maintain voltage magnitude, provide stability, and enable black start—the process of starting up a grid if it goes down. Several advances in grid-forming inverters have not been validated at scale but can be leveraged during the demonstration of a resilient community grid.[87]

SETO is looking to raise round-trip efficiency, minimizing energy lost during transfer from a DER to storage and then to the loads in microgrids, as well as reducing the capital costs for the installation of new systems. While the majority of electricity is generated, transmitted, and used in alternating current (AC), direct current (DC) microgrids may provide increased efficiency, power quality, and reliability.[88] The main sources of DC power supply are photovoltaic (PV) panels and fuel cells, but a recent study showed that medium voltage DC (MVDC) distribution would be more cost-effective compared to a

[83] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/sustainable-and-holistic-integration-energy-storage-and-solar-pv-shines

[84] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/enabling-extreme-real-time-grid-integration-solar-energy-energise

[85] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/grid-modernization-initiative-0/resilient-distribution-systems-lab-call-awards

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

[87] *IEEE Power and Energy Magazine*. "Grid-Forming Inverters: Are They the Key for High Renewable Penetration?" November–December 2019. https://ieeexplore.ieee.org/document/8879610.

[88] Shekhar, A. et al. "Grid Capacity and Efficiency Enhancement by Operating Medium Voltage AC Cables as DC Links with Modular Multilevel Converters." *Electrical Power and Energy Systems* 93, 479-493 (2017)

variety of distribution options.[89] Several advances for protection in MVDC circuits can be leveraged to enable more reliable DC grids.[90]

Topic Description and Goals

SETO seeks to support the development of resilient community microgrids with solar penetration greater than 75% of microgrid peak load. ENERGISE projects have demonstrated operations at >50% peak loading and communications with >10,000 nodes. Above these levels, there are challenges with the coordination and optimization of resources that this topic aims to address. These grids should provide electricity during a disaster and improve reliability to the area power system while connected to the bulk grid or not. To achieve that goal, the objective of this topic is to develop solutions that enable DER assets to quickly respond to centralized commands through scalable layered controls, so that communities will have increased resilience and maintain continuity of power to critical assets.

Resilient community microgrids will encompass feeder-level microgrids with multiple points of common coupling to the surrounding distribution grid. To support the needs of local populations and critical infrastructure during extended grid outages, proposals must consider diverse DER options, like energy storage, wind, and flexible loads, in addition to PV. While DC grids have potential efficiency and operational advantages, communities typically will not have the ability to immediately transition to a DC grid and will require a hybrid AC/DC microgrid. This makes coordinating the operations and protection of the microgrid's AC and DC sections challenging. Utility involvement with the integration of DC grids to existing AC grids will be essential, and the interaction between these systems—protection coordination, normal operations, metering, etc.—must be described in the application.

Communities are subject to regional differences in outage causes—high wind, flooding, wildfires, extreme cold—which may require numerous microgrid capabilities. Critical services required to respond to outages and the level of response needed will vary based on the event type, which will provide a design challenge. Therefore, one solution may not be appropriate for all locations but should contemplate scalability to broader conditions.

A resilient community grid, as defined for this FOA, consists of:

- Solar PV penetration greater than 75% of microgrid peak load with a minimum PV capacity of 1 MW, including utility, residential, commercial, and/or community solar facilities

[89] Reed, G. et al. "Medium Voltage DC Technology Developments, Applications, and Trends." CIGRE US National Committee 2012 Grid of the Future Symposium (2012).
[90] U.S. Department of Energy Advanced Research Projects Agency–Energy (ARPA-E). https://arpa-e.energy.gov/?q=arpa-e-programs/breakers

- Multiple (hundreds to thousands), independently owned and operated buildings, and likewise many (>10,000) DER that act as a group of interconnected loads and generation
- A variety of behind-the-meter and front-of-the meter DER that support critical service facilities
- DER interconnected to the area electric grid, which supports grid reliability during normal operations and has the ability to island during abnormal conditions or outages. Project funds may be used for usage fees to cover energy from DER during the course of the project and potential lost revenues during simulated outages. Applicants should not propose to use funds to construct DER installations.
- The ability to island the whole resilient community grid, which may include additional sectionalizing or even ad-hoc microgrids, as smaller microgrids may form within the resilient community grid when it is experiencing abnormal conditions
- Innovative microgrid feeder designs, which may lower infrastructure costs, increase efficiency, provide higher asset utilization, and better integrate inverter-based resources
- One or more critical community service facilities, with examples noted in Table 2, below
- Innovative microgrid technologies, such as:
    - Fully synchronized, multiple-point-of-common-coupling (MPCC) islanding
    - Nearly commercial grid-forming solar PV solutions
    - MVDC distribution or hybrid AC-DC topologies
    - DC and/or hybrid protection systems
    - Advanced microgrid control systems development

Facilities that provide critical services include but are not limited to:
• Hospitals, medical facilities • Emergency shelters, evacuation centers • Police departments, fire stations, emergency responders • Critical communication and data systems • Water pumping and wastewater treatment plants

Table 2. *Critical service facilities*

Successful applicants should provide a detailed description of the state of the art, the advances they propose, and a detailed plan for R&D efforts, including:

- Management of grid services in scenarios of greater than 75% PV penetration (with respect to peak load) with coordination of >10,000 DER

- Control and communications architecture during interconnection with the area electric grid for normal operations, and again during island mode (if different)
- Operations in various communications scenarios, like loss of all communications, intermittent communications, or only local communications within the system, and the transition from one communication scenario to another
- Automated fault location, isolation, and restoration
- Black start of islanded sections using DER and conventional generation
- Interface with utility systems, including legacy equipment
- Coordination of AC and DC protection systems
- Cybersecurity plan
- DER and utility interoperability plan

Applications should describe hardware and/or software research on 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. All projects are required to do hardware in the loop (HiL) testing to validate controls prior to field trials. The required field trial needs to show, at a minimum, how the solution can provide power to emergency services during simulated outages with high penetration DER.

Teams must include sufficient stakeholder commitment, especially from the distribution utility, depending on the scale of microgrid sought. Teams must plan to engage with local government representatives prior to demonstration to discuss any potential regulatory and policy issues related to implementation.

Grid resilience metrics can be measured using direct and indirect methods. A cost-benefit analysis will be required to demonstrate the cumulative effect of implementing the proposed solution on normal operations for the community, as well as compared to state-of-the-art emergency generation systems. Applicants must define performance metrics to show how the proposed solution will enhance resilience, based on the host community's needs.

Consequence Category	Resilience Metric
Direct	
Electrical Service	• Cumulative customer-hours of outages • Cumulative customer energy demand not served • Average number (or percentage) of customers experiencing an outage during a specified time period

Critical Electrical Service	• Cumulative critical customer-hours of outages • Critical customer energy demand not served • Average number (or percentage) of critical loads that experience an outage
Restoration	• Time to recovery • Cost of recovery
Monetary	• Loss of utility revenue • Cost of grid damages (e.g., repair or replace lines, transformers) • Cost of recovery • Avoided outage cost
Indirect	
Community Function	• Transit time for residents to obtain basic needs (food, medicine, etc.) • Maintenance of transportation (public and private) infrastructure for evacuation
Monetary	• Loss of assets and perishables • Business interruption costs • Impact on gross municipal product or gross regional product
Other Critical Assets	• Key defense facilities without power

Table 3. *Examples of grid resilience metrics*[91]

Applications Specifically Not of Interest

Applications will be deemed nonresponsive and declined without external merit review if they:

- Seek to develop campus-style or single-facility microgrids, which have single points of common coupling and reflect the current state of the art
- Propose microgrids that are not connected to the area power grid during normal operation
- Propose extensive power electronics design and development. Applicants should instead focus on integrative, system-level designs that have a practical deployment timeline for field trial.
- Do not include a field trial of the technologies. Final demonstration in a laboratory setting is insufficient.

Topic Area 5.2: Addressing Cybersecurity Gaps

[91] Grid Modernization Laboratory Consortium 1.1 Reference Manual. https://gmlc.doe.gov/projects/1.1

This topic will support R&D, and requires demonstration, of technology solutions that improve the cybersecurity of operations systems used by DER aggregators[92] and electric utilities to manage PV inverters and other DER. The goal of this topic is to lay the groundwork for a cyber-resilient power system that will be able to recognize and reject a cyberattack arising from DER automatically and adjust as necessary to keep the lights on, while isolating and removing the cyber threat. These future systems will recognize and refuse to take any action that does not support grid stability, and will perform only the well-defined functions for which they are designed.

Because DER are geographically broadly dispersed, DER can make the electric grid more resilient, but as more solar PV and other DER are added to the grid, new cybersecurity vulnerabilities and challenges arise. This risk used to be relatively minor, given how few systems were deployed and because many solar inverters in use today do not use communications to monitor or control their output. With publication of the Institute of Electrical and Electronics Engineers (IEEE) 1547-2018[93] DER interconnection standard, which now requires communications capabilities and DER grid support functions during abnormal electric grid conditions, the solar and DER industry must address the inherent cybersecurity vulnerability the growth of such devices may present.

DER introduce information exchanges between a utility or aggregator control system and the DER to manage the electric grid. Given the historical lack of cybersecurity focus for DER information exchanges, they often don't have the communications security present in traditional utility systems. Additionally, the operating characteristics of DER are dynamic and very different from those of traditional generation capabilities, so they require a higher degree of automation. Managing the automation, the increased need for information exchanges, and the cybersecurity associated with these systems presents significant challenges—complicated by the large number of owners and operators involved with DER.

This topic seeks research, development, and demonstration (RD&D) to address the cybersecurity challenges of grid operations resulting from DER, especially for operational technology systems used by DER aggregators and utilities. Cybersecurity vulnerabilities exist in the communications networks between DER aggregators, utilities, and DER sited at homes and businesses. DER aggregators may have various DER control systems that gather communications from DER, routing them to application servers for optimization and coordination routines. Control requests may then return to the DER, or DER availability may be sent to the utility's systems for optimization and coordination with other grid assets. DER may also integrate directly into a utility's systems, routing through

[92] This article describes the emergence and role of DER aggregators: https://www.utilitydive.com/news/der-aggregation-sector-experts-identify-emerging-trends-in-a-nascent-marke/447670/

[93] IEEE 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces. https://standards.ieee.org/standard/1547-2018.html

the internet and into the utility's DER server. All of these communications pathways and applications may be vulnerable to cyberattack. Of particular interest are systems at the DER aggregator- and utility-level, as opposed to the systems of DER sited at homes and businesses.

Developing a cyber-resilient power system requires more than just a focus on communication networks. While there are similar challenges across the cyber community for communications and information technology, DER and power systems professionals must also consider the physical nature of the grid. Cyberattacks impact grid operations governed by laws of physics on how power flows on the grid and not just data exchanges. A communications attack on DER, loads, or generation could therefore change the power flow on the grid and cause physical damage, plus create wider safety and health issues. The cyber-physical security of the electric grid—a critical infrastructure—supports national resilience, and new DER will need enhanced defenses. As a result, SETO is focused on innovative cyber-physical R&D for DER in grid operations.

Research Background and State of the Art

To address these emerging vulnerabilities, SETO has supported cybersecurity research for solar and DER. This includes Sandia National Laboratory's "Cybersecurity Primer for DER Vendors, Aggregators, and Grid Operators" report[94] and "Roadmap for Photovoltaic Cyber Security."[95] Existing SETO and GMLC research awards[96] address cybersecurity at the individual device level (e.g., solar inverters), while the topic described in this FOA focuses on cybersecurity issues for integrating solar and DER into aggregator and utility operations. SETO coordinates with the Office of Cybersecurity, Energy Security, and Emergency Response (CESER) on its cybersecurity efforts, and applicants should consider that office's multiyear plan goals[97] when developing their proposed research projects.

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[94] Sandia National Laboratories. *Cyber Security Primer for DER Vendors, Aggregators, and Grid Operators.* 2017. https://www.researchgate.net/publication/322568288_Cyber_Security_Primer_for_DER_Vendors_Aggregators_and_Grid_Operators

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

[96] Existing SETO systems integration (SI) awards support cyber indirectly through the ENERGISE and ASSIST funding programs, and directly for FY19-21 Lab Call and FY19 SETO FOA awards. SETO SI also co-funds and helps manage the latest round Grid Modernization Laboratory Consortium cyber awards.

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

Cybersecurity capabilities for solar and DER technology rely upon methods and tools to identify, detect, protect, respond, recover, and endure[98] a cyberattack—categories based on the National Institute of Standards and Technology's (NIST) cybersecurity framework (CSF),[99] which was released to better guide cybersecurity activities and risk management processes. We are adding *endure* to incorporate resiliency elements, such as using DER to form microgrids in the event of an area power system outage.

Innovative applications of these defenses may include identifying and protecting against new vulnerabilities from DER, enriched cross-domain detection schemes for customer-device-to-utility-controls systems attacks, automated response and recovery techniques, and resiliency to endure multi-vector attacks through decentralization and graceful degradation.

[98] Identify, Detect, Protect, Respond, and Recover are categories of activities under the NIST cybersecurity framework: https://www.nist.gov/cyberframework. This framework is conceptually extended to include Endure as a category to capture resiliency aspects within a cybersecurity framework. Framework adapted from Jovana Helms at Lawrence Livermore National Laboratory.
[99] NIST cybersecurity framework: https://www.nist.gov/cyberframework

This FOA topic aims to holistically address cybersecurity through an overall dynamic survival strategy, which is aligned with the DOE CESER Multiyear Plan for Energy Sector Cybersecurity.[100] Sophisticated attacks are always shifting and creating new vulnerabilities, so survival strategies should be dynamic and evolve to maintain critical capabilities. As shown in Figure 14 a dynamic survival strategy applies defense-in-depth[101] approaches through organized, continuous risk management. Defense-in-depth uses multiple security techniques to help mitigate the impact of one component being compromised or circumvented, and likewise can mitigate more than one attack vector. For example, virus protection can be achieved through anti-virus software installed on the DER, as well as virus protection and detection on the firewalls and servers that integrate DER into aggregator controls. Malicious malware, therefore, may be detected within the DER or, if compromised, detected and mitigated by the aggregator's software. Defense-in-depth for DER integrated onto the grid is more complex than component or individual technology defense, given the multiple owners, potential operators, and systems of systems involved. These defense-in-depth approaches should therefore be layered and meshed, as part of a holistic, dynamic survival strategy.

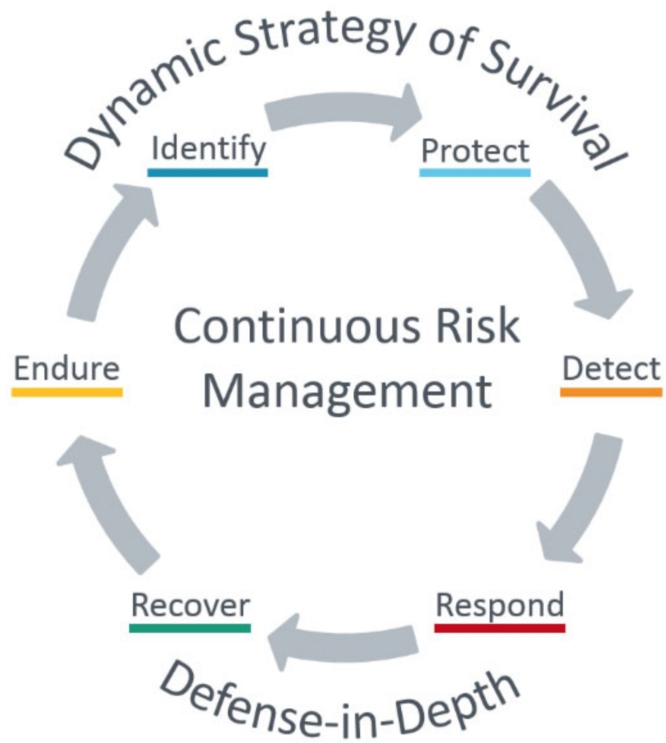

Figure 14. *A dynamic survival strategy applies a defense-in-depth approach and continuous risk management across and within the CSF categories.*

Figure 15 maps NIST's CSF defense efforts to adversary-sophistication categories[102] and gives examples of innovation needed for the most sophisticated attacks. In Figure 15, the NIST CSF effort categories appear on the left. The other columns highlight how CSF efforts must be extended and layered to address attacker sophistication.

[100] Ibid 94.
[101] U.S. Department of Homeland Security. "Defense in Depth." Barnum, et. al. 2005. https://www.us-cert.gov/bsi/articles/knowledge/principles/defense-in-depth
[102] Generalized relative to DHS CISA Cyber Threat Source Descriptions: https://www.us-cert.gov/ics/content/cyber-threat-source-descriptions

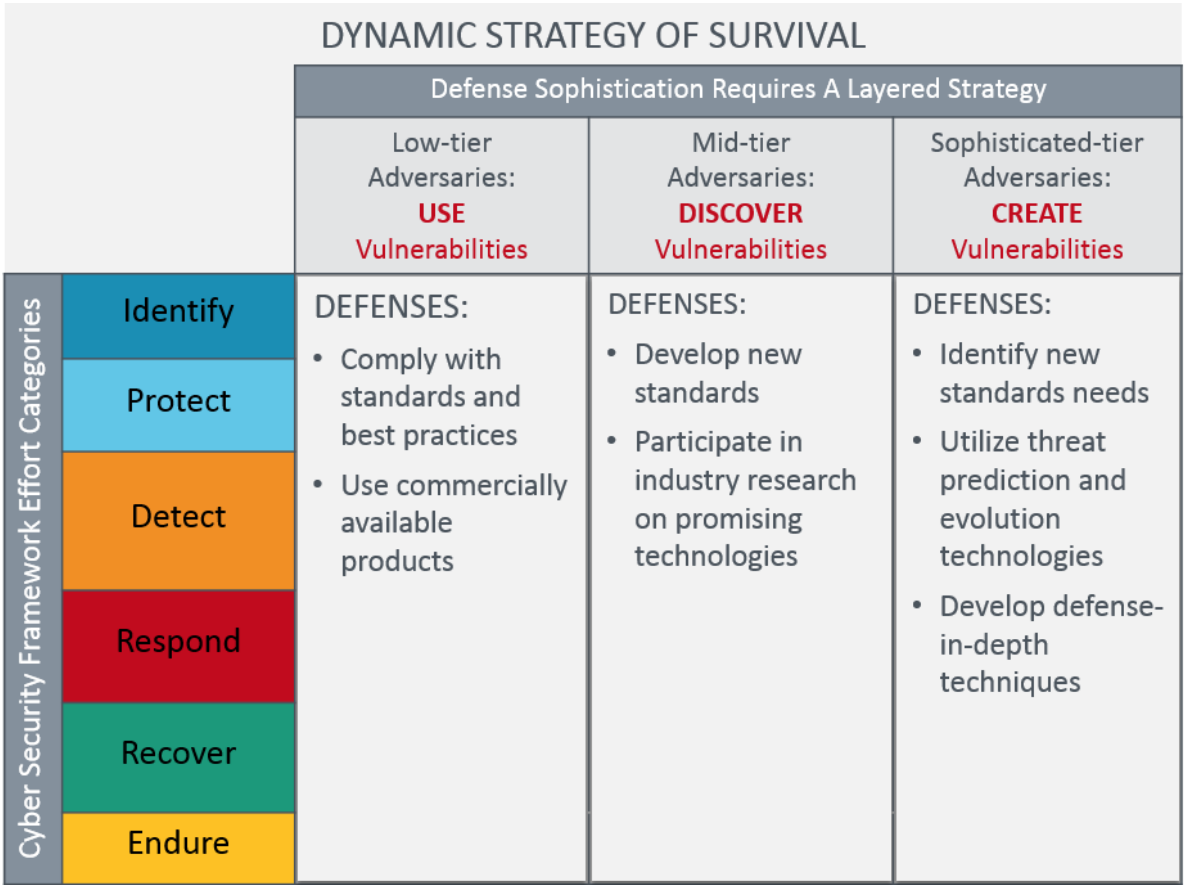

Figure 15. *Cyber defense requires a layered strategy*[103]

As indicated by the columns, from an attacker's viewpoint, low-tier adversaries use existing vulnerabilities, such as failure to patch equipment for known weaknesses. Low-tier attacks are typically mitigated using commercially available products, implemented according to best practices and in compliance with standards.[104] Mid-tier attackers, on the other hand, discover new vulnerabilities, given their coordinated, multi-member commitment and wider motivations. Sophisticated-tier attacks come from large organizations with dedicated teams who can spend months or years attempting to *create* and exploit vulnerabilities. Mitigating mid- and sophisticated-tier attacks, requires deploying and testing new technologies as part of a defense-in-depth approach across and within CSF effort categories. Effective mitigation of sophisticated attacks predicts where they may evolve, implements survival mechanisms, and further develops multiple, overlapping or meshed defense-in-depth techniques.

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[103] This and subsequent CSF vs. Adversary Sophistication figures are adapted from figures by Jovana Helms at Lawrence Livermore National Laboratory.

[104] Note that SETO is addressing DER and aggregator compliance with support for standards development by National Labs. For more information, see the Sandia & SunSpec Cybersecurity Work Group: https://sunspec.org/cybersecurity-work-group/

Taken as a whole, a robust, dynamic survival strategy implements multiple, mixed, and layered defense-in-depth techniques in a proactive and increasingly automated manner—especially for mid- and sophisticated-tier attacks. Indicative of sophisticated defenses across the CSF categories, protection and control equipment can, for instance, check that a received command supports grid stability (*command verification*), given the current operational circumstances. If the received command instead jeopardizes grid stability, it can be considered malicious and automatically rejected (*automated response*). This verification and rejection is more robust as a layered approach, perhaps both at the device level and the system level. Likewise, operational networks might dynamically reconfigure to route around a cyber incident (*dynamic networking, quarantine*), while sustaining critical functions (*fail-to-safe*), or microgrids may form (*decentralization*) to ensure critical facilities isolate and endure the cyberattack.

A dynamic strategy of survival also includes organizational and business environment elements, addressing governance, management, and continuous cyber hygiene. A holistic, dynamic strategy for survival includes:

1. Applying a continuous CSF defense
2. Using multiple defense-in-depth cybersecurity methods through a layered strategic approach[105] for low-tier and sophisticated-tier adversaries
3. Maturing organizational implementation[106] of cybersecurity
4. Organizing and refreshing these three dimensions listed above for continuous risk management

Taken together, these efforts reflect an example of a survival strategy, applying multiple defense-in-depth methods for certain types of attacks.

Topic Description and Goals

The goal of this research is to support the development of innovative, dynamic cybersecurity survival strategies for DER aggregators and utilities, especially as solar energy is becoming a rapidly growing percentage of energy supply in many areas. This topic supports RD&D that will work toward a trustworthy, cyber-resilient power system. This system will be able to recognize and reject a cyberattack automatically and autonomously and adjust to keep the lights on, while isolating, encapsulating, and removing the cyber threat. DER and utility systems will be able to recognize threats and refuse to take any action that does not support grid stability, performing only the functions for which they are designed.

[105] Layered approaches implements parallel systems of defense, especially for sophisticated multi-vector attacks.

[106] Electricity Subsector Cybersecurity Capability Maturity Model (ES-C2M2). https://www.energy.gov/ceser/activities/cybersecurity-critical-energy-infrastructure/energy-sector-cybersecurity-0-1

The main objective of this topic is to develop and field-validate enhanced cybersecurity capabilities for cyber-physical power systems, focused on innovative defense-in-depth RD&D for solar PV and DER aggregator systems and utility systems.[107] DER aggregators and utilities should gain a holistic survival strategy for their operational systems that aligns with the CSF defensive efforts to combat adversary sophistication, presented above in Figure 15.

Applications should seek to strengthen aggregator and utility systems such that solar and other DER can enhance grid resilience. This topic seeks innovation across solar CSF defensive efforts: identifying, detecting, protecting, responding, recovering, and enduring a mid- to sophisticated-tier attack. At the same time, cyber-physical threat models and predictive attack evolution techniques need to be developed that mitigate impacts of malicious DER on power system stability and resiliency. With further DER growth, a systems-of-systems cyber threat model needs to be developed to mitigate sophisticated attack vectors that instigate abnormal power flow, cause instabilities like sub-synchronous resonance, or amplify weak grid conditions[108] that could lead to cascading outages.

While the main objective of this topic is to develop defense-in-depth cyber approaches, there may be secondary R&D objectives for single-issue cyber-physical grid operations. Each of the following examples may be considered secondary R&D objectives because they reflect narrow cyber-physical risks compared to the holistic, dynamic survival strategy goal sought for aggregator and utility systems.

Secondary objectives may target contingency events such as DER influencing under frequency load shed, DER support for black start, or malicious DER introducing electrical disruptions like inter-area oscillations and sub-synchronous resonance. These objectives may be narrow technology or application focuses, such as attack-resilient protection technology or distributed energy resource management system (DERMS) cybersecurity. Specific technologies or contingency events may, for example, reflect attack use cases for assessing defense-in-depth capabilities relative to an overall survival strategy.

While testing innovative R&D technologies in a field trial, projects under this topic may support deployment of existing cyber best practices in the field. However, no more than 20% of the proposed budget should be used to implement cybersecurity based on existing and nearly developed standards and current best practices.

[107] See again Figure 2 for example DER aggregator and utility systems.

[108] Weak grids are used here generically. An example, specific weak grid type is described in IEEE/NERC 2018: Institute of Electrical and Electronics Engineers (IEEE)/North American Electric Reliability Corporation (NERC) Task Force on Short-Circuit and System Performance Impact of Inverter Based Generation. 2018. Impact of Inverter Based Generation on Bulk Power System Dynamics and Short-Circuit Performance.

As solar deployment continues to grow rapidly in many regions, resilient solar needs to play a strategic role in supporting critical U.S. infrastructure, including but not limited to the 16 sectors.[109] Applicants are encouraged to develop partnerships to demonstrate improved resiliency to critical national security assets, such as defense facilities and surrounding areas.

Performance Metrics and Innovation Attributes

Performance for a survival strategy will depend on the specific DER aggregator and/or utility systems and the nature of the attacks. Applicants are encouraged to propose a survival strategy plan that includes various defense-in-depth R&D approaches across the cybersecurity activities for secure DER integration into grid operations. RD&D should focus on mid- and sophisticated-tier defenses. Therefore, a robust testing and evaluation plan must include performance metrics for specific cyber technologies.

For demonstration, applicants are encouraged to work with critical infrastructure[110] owners and operators, industry, academia, and other stakeholders, including states, local government entities, tribes, and territories to improve resiliency to critical national security assets, such as defense facilities and surrounding areas. Improvements would include resiliency during regional outages and rapid recovery following the outage.

Applicants should:

- Propose a robust, dynamic survival strategy plan for cyber-physical defense-in-depth RD&D for DER aggregators and/or utility operations
- Define the industry state of the art and map their proposed development to performance metrics to test and validate their defense-in-depth technologies
- Specify the proposed cyber-physical architecture: communications and grid networks
- Ensure upfront vendor participation in vulnerability assessments and mitigation plans
- Describe a plan to use specific proprietary communications protocols, if any
- Indicate why the proposed strategy for survival is innovative. Applicants may use the NIST CSF versus Adversary Sophistication figures presented above to conceptualize their defense-in-depth RD&D focus(es).
- Include interoperability for information technology and operational technology systems

[109] U.S. Department of Homeland Security. https://www.dhs.gov/cisa/critical-infrastructure-sectors

[110] Critical infrastructure means systems and assets, whether physical or virtual, so vital to the United States that their incapacity or destruction would have a debilitating impact on security, national economic security, national public health or safety, or any combination thereof. (42 USC 5195c(e))

- Address how their approach will practically provide systems cybersecurity—from DER owners, DER vendors, aggregators, to utilities, given the multiple owners and stakeholders involved—for DER integration in grid operations. Applications should address data-in-flight security.

Areas of Interest

- Exploration of defense-in-depth cyber-physical security RD&D as part of a proactive survival strategy, especially for mid- and sophisticated-tier attacks.
- Inclusion and use of secure integration of solar PV communications and control signals into aggregator and/or direct utility operational systems. Beyond solar PV, other priority DER, such as fast electric vehicle charging or high-wattage controllable loads, may be included in the research. Successful approaches should be extendable to broader DER technologies. Direct DER interfacing into utility operations are eligible.
- Research to prevent malicious attacks to individual units at the local level and their propagation to centralized or distributed systems.
- Support technologies for local reliability and resilience, especially for defense critical facilities.
- Machine learning and automated response and recovery through artificial intelligence.
- Research to identify needs for new standards, including creation of industry reports on suggested requirements and a standard framework.

Applications Specifically Not of Interest

Applications will be deemed nonresponsive and declined without external merit review if they:

- Do not address mid- and sophisticated-tier threats
- Do not include a field trial of the developed technologies
- Focus on devices for broad energy internet-of-things (E-IoT) cybersecurity. Focus should instead be on DER aggregators and utility operational systems for secure integration of solar inverters, potentially also including PV plant controllers and other large-wattage DER devices, such as electric vehicle charging and battery energy storage.
- Involve ancillary third parties who gather and use solar data for purposes other than grid operations, such as financial monitoring or insurance risk quantification
- Focus on equipment and systems supply-chain security as a major proportion of the proposed research.
- Focus on business-enterprise IT cybersecurity. Focus should instead be on cyber-physical grid operational systems for providing DER customer and/or grid services.

- Propose incremental advancement to existing or near-term standards. Projects for extensive standards development are not of interest
- Seek to develop strategic organizational change, workforce, and technology support services to address cybersecurity concerns

Topic Area 5.3: Control and Coordination of a Hybrid PV Plant

This topic area seeks research that advances control and coordination of hybrid PV plant technologies to address current limitations of hybrid PV plants in providing flexibility, stability, and grid-forming capability. This research will increase the value of solar as it begins to operate collaboratively with other resources in a hybrid PV plant for improved reliability and resilience.

A hybrid PV plant[111] in this FOA is defined as a group of PV and one or more generation or storage resources, such as wind, batteries, pumped hydro or fuel cells, that is connected as a single resource to the grid. Such a hybrid plant provides an opportunity to internally optimize and coordinate in a way that will provide enhanced grid stability and grid services. For example, a PV-plus-storage hybrid plant can be designed to provide energy at any time of day.

This research will also work to develop new grid-forming capabilities of solar PV at the bulk grid. Traditional "grid-following" PV systems require an outside signal from the electrical grid to inject power into the grid. In these systems, the power from the grid provides a signal that the inverter tries to match. More advanced grid-forming inverters can generate the signal themselves.

Renewable electricity generation is projected to account for over 30% of the U.S. electricity supply in 2050, according to the U.S. Energy Information Administration Annual Energy Outlook 2019.[112] Of the 30% renewables, nearly half will come from solar PV and the rest from wind, hydro, geothermal, and other sources. Electricity from solar and wind is variable, meaning it fluctuates throughout the day, and requires the grid operator to use other generation sources to balance the grid. Storage, like batteries and pumped hydro, could also offset variability, and solar inverters could provide advanced grid services to help grid operators match demand and supply.

Today, grid operators rely primarily on gas-powered plants or pumped hydro to ramp up quickly and manage variability in electricity supply. There is an opportunity for the individual resources to co-locate. This would enable them to better coordinate and use their potential flexibility to improve variability management and provide advanced grid

[111] National Renewable Energy Laboratory. *Hybrid Utility-Scale PV-Wind Storage Plants for Dispatchability and Reliability Services.* Gevorgian, et. al. 2018. https://www.nrel.gov/docs/fy18osti/71551.pdf
[112] EIA *Annual Energy Outlook 2019.* https://www.eia.gov/outlooks/aeo/

services. Flexibility in generation refers to the capability of generators to start and stop easily, increase or decrease generation on demand, and respond quickly to ensure stability and reliability. The hybrid PV plant model in this FOA topic would operate the plant as a single, flexible generating resource. This topic addresses technological challenges both within a hybrid PV plant and in coordination with multiple hybrid PV plants.

The hybrid plant concept has been adopted by many industries worldwide, from few megawatts (MW) in size to several hundred MW.[113] In a September 2019 workshop[114] organized by the North American Generator Forum, the North American Electric Reliability Corporation, and Energy Systems Integration Group, electric industry representatives discussed the advantages of hybrid plants. One of the most common types of hybrid plant is solar-plus-storage. In 2016, SETO ran the Sustainable and Holistic Integration of Energy Storage (SHINES) funding program, which focused exclusively on connecting solar power to storage. The solutions developed under this program incorporated dynamic load management, advanced forecasting techniques, utility communication and control systems, and smart buildings and smart appliances to work seamlessly to meet both consumer needs and the demands of the electricity grid at lowest cost. However, from a grid operation perspective, these early solar-plus-storage hybrid plants still operate with limited flexibility and limited market participation.

Key technological challenges that remain for hybrid PV plants include providing enhanced grid services, flexibility, AC/DC coupling, coordinated control, and emerging grid-forming capabilities, to name a few. This topic specifically looks at advancing hybrid PV plant technologies to enable greater flexibility and value for the bulk grid.

The scope of hybrid plant research for this FOA is organized into two research areas:

1. Internal hybrid plant design and control
2. Control and coordination among hybrid plants

Projects may address one or both of these research areas. Successful projects will create and field-test a suite of tools, software, and firmware that enhance the functionality of hybrid PV plants so that they may be grid forming and flexible in generation. The first area of research is focused on the design and control of a single hybrid PV plant with generation capacity greater than 20 MW. While there's been progress in developing hierarchical controls and cost optimization of resources within a hybrid plant, enhanced

[113] 5th International Hybrid Power Systems Workshop: http://hybridpowersystems.org/

[114] NERC/NAGF/ESIG Battery Storage, Hybrid Resources, Frequency Response and Grid Services Workshop: https://www.esig.energy/event/nerc-nagf-esig-battery-storage-hybrid-resources-frequency-response-and-grid-services-workshop/

flexibility tools are still limited. As an example, current state of the art is restricted to grid-following hybrid plants. These plants cannot provide a voltage source at the point of common coupling, which limits their ability to offer enhanced grid stability and grid services. Providing enhanced grid-forming controls[115] within the hybrid plant would enable the plant to jumpstart the grid when it is down, stabilize the grid under low inertia, and provide voltage and frequency regulation. The topics of interest for internal hybrid PV plant design and control include:

- Novel optimization approaches within a hybrid plant to holistically optimize for cost, efficiency, reliability, and performance among multiple generating resources
- Advanced grid-forming controls, including each inverter based resource (IBR) separately within the hybrid plant, if AC-coupled
- Provision of enhanced grid services, such as optimal dispatch, flexible generation, predictable output, enhanced inertia control, and other services that were not previously possible with individual plants
- Novel AC and/or DC coupling of different IBR within a hybrid plant for improved power conversion efficiency
- Integrating controls among multiple IBR, which may include novel combinations of wind, solar, fuel cells, batteries, supercapacitors, and other IBR
- Enhanced accuracy in forecasting internal hybrid-plant output, which will enable high confidence in market participation by the plant operator

The second area of research is control and coordination between multiple hybrid PV plants. Current state of the art has focused on one hybrid plant, but there are opportunities for a combination of hybrid plants to improve the reliability of the power grid when they are co-managed inside the same balancing area but not necessarily co-located. The topics of interest for this area of research include:

- Steady-state and dynamic modeling of hybrid plants with grid-forming capabilities at various time scales
- Enhanced stability for the overall bulk grid, contributed by a set of hybrid plants
- Grid-forming and frequency control by a set of hybrid plants
- Other novel control and coordination strategies among hybrid plants to provide enhanced flexibility

It is important to address the economic considerations so that hybrid PV plants continue to be relevant. The research topics can be supplemented with economic considerations, with participation by plant owners, operators, utilities and ISOs, which include:

- Reduction of capital expenditures and O&M costs
- LCOE calculations and reduction methods
- Ability for enhanced market participation

[115] J. Matevosyan, et al. "Grid-Forming Inverters: Are They the Key for High Renewable Penetration?" *IEEE Power and Energy Magazine*, vol. 17, no. 6, pp. 89-98, Nov-Dec 2019.

Performance Metrics for Topic Area 5.3

- Plant design and operation should be in alignment with North American Electric Reliability Corporation (NERC) reliability standards.[116] Innovative capabilities for grid forming or other enhanced grid services should inform the IEEE P2800 standard development[117] via public reports, testing outcomes, or other disseminated deliverables that industry can use to advise the proposed standard.
- Applicants are encouraged to develop metrics for plant flexibility.
- Individual resources within a hybrid plant should be mostly co-located and connected at a single point of common coupling or interconnection with the bulk grid.
- Each hybrid plant should be at least 20 MW due to the topic focus on bulk grid integration.
- For plants with multiple IBR, each IBR within the hybrid plant must provide grid-forming controls if AC-coupled, including at the point of common coupling to the bulk grid.
- Each hybrid plant should provide higher reactive-power capability, with a power factor ranging from ± 0.75.
- Each hybrid plant should provide black-start resources when in need and form the grid in less than one second.
- Each hybrid plant should accurately follow the Automatic Generation Control (AGC) signal.
- Hybrid plant(s) should enhance dynamic transient stability under fault conditions.
- Hybrid plant(s) should provide primary and secondary frequency control.
- Field validation of the hybrid PV plant is expected at a minimum of 1 MW. Applicants may retrofit existing PV plants or use large-scale testing facilities or other means to field validate at 1MW. Under this topic area, DOE will not fund applicants to design or build hybrid PV plants.
- Applicants should prove scalability of algorithms to 20 MW or higher, in a controlled environment or lab simulations.

Applications Specifically Not of Interest

Applications will be deemed nonresponsive and declined without external merit review if they:

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[116] North American Electric Reliability Corporation: https://www.nerc.com/pa/Stand/Pages/ReliabilityStandards.aspx

[117] Institute of Electrical and Electronics Engineers (IEEE) - P2800 - Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems: https://standards.ieee.org/project/2800.html

- Look only at economic considerations
- Propose engineering designs or construction of a hybrid PV plant
- Propose control and coordination of hybrid PV plants smaller than 20 MW, as per the Federal Energy Regulatory Commission Small Generator Interconnection Agreement[118]
- Concentrate on off-grid and backup hybrid plants
- Propose extensive standards development

vi. Topic Area 6: Solar and Agriculture: System Design, Value Frameworks, and Impacts Analysis

This topic area will build upon and expand ongoing SETO projects related to the co-location of solar and agriculture by developing technology, evaluating practices to date, and conducting research and analysis that enable farmers, ranchers, and other agricultural enterprises to gain value from solar technologies while maintaining availability of land for agricultural purposes. The goal is to facilitate and expand the co-location of solar and agricultural activities where it is beneficial to both industries and to the local community. For this topic, co-location is defined as agricultural production (i.e., crop or livestock production, or pollinator habitat) underneath solar panels and/or in adjacent zones around the solar panels.

Background

Ground-mounted solar PV deployment is projected to increase from 32 GW of installed capacity[119] to 92 GW by 2030,[120] which is estimated to require less than 0.1% of the land in the contiguous U.S.[121] Although the land requirements are a small percentage of the country, the growth in ground-mounted solar can create local land-use competition with agricultural land. The co-location of solar PV and agriculture could provide agricultural enterprises with diversified revenue sources and ecological benefits, while reducing land-use competition and siting restrictions.[122] Current system designs and business practices, however, are not optimized to enable simultaneous land use for multiple industries.

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[118] Federal Energy Regulatory Commission. https://www.ferc.gov/industries/electric/indus-act/gi/small-gen.asp

[119] As of August 2019: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_01_a

[120] See Table 16: https://www.eia.gov/outlooks/aeo/tables_ref.php

[121] Land-use percentage based on 181 GW of PV and 28 GW of CSP: https://publications.anl.gov/anlpubs/2016/10/130700.pdf

[122] *Agrivoltaics Provide Mutual Benefits Across the Food–Energy–Water Nexus in Drylands*. Barron-Gafford, G.A., Pavao-Zuckerman, M.A., Minor, R.L. et al. *Nature Sustainability* 2, 848–855 (2019). https://www.researchgate.net/profile/Greg_Barron-Gafford/publication/335583033_Agrivoltaics_provide_mutual_benefits_across_the_food-energy-water_nexus_in_drylands/links/5da87eda4585159bc3d5a0e7/Agrivoltaics-provide-mutual-benefits-across-the-food-energy-water-nexus-in-drylands.pdf?origin=publication_detail

Except for growing pollinator habitat at solar facilities, today the co-location of solar and agriculture is primarily limited to research sites. Most large, ground-mounted solar systems are installed on land used only for solar energy production. System designs are optimized for cost and energy output by using low support structures that reduce wind loading and material requirements, and by maximizing ground coverage of modules. Exploring alternate solar system designs and operating practices that optimize both energy and agricultural production at co-located sites may offer opportunities to increase overall value.

New frameworks need to be developed to overcome barriers to the co-location of solar and agriculture. One of these barriers is understanding the value of co-location to the asset owner, system operators, and other stakeholders. Existing frameworks and approaches do not take both the solar and agricultural components into account. System value considerations include established metrics, such as electricity generation, grid services, crop and livestock production, and water usage intensity, as well as values that are more challenging to quantify, such as the economic and ecological benefits of pollinator habitat grown under solar systems.

Additional research on the ecological benefits and costs of solar and agricultural co-location is needed to quantify these values and develop best practices that apply to regional conditions. Another area for expanded research is the interaction of birds with co-located solar and agriculture, pollinator habitat, and native plant species. While co-location could attract and provide habitat for birds, it could also impact avian mortality and panel performance and make monitoring nests and mortality more challenging.

SETO has funded projects that have begun to examine these co-location questions. A small portfolio of Small Business Innovation Research projects are researching solar technologies for complementary use on agriculture land, including both livestock and crops.[123] Through the Innovative Site Preparation and Impact Reductions on the Environment (InSPIRE) project, the National Renewable Energy Laboratory (NREL) is leading field-based research across the United States and analytical studies to investigate the viability of growing crops and pollinator habitat underneath solar panels, the agricultural yields of the crops, and the ecological services provided by co-location.[124] NREL is also researching stormwater infiltration and runoff at solar sites, including sites with agriculture and pollinator ground cover; validating a model to understand, predict, and manage water resources; identifying best practices for stormwater management; and

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[123] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/funding-opportunity-announcement-small-business-innovation-research-and-small-business-1

[124] InSPIRE project overview: https://openei.org/wiki/InSPIRE/Project

engaging with local jurisdictions.[125] In addition, SETO supported technical assistance to the Multiagency Avian-Solar Collaborative Working Group, led by federal and state agencies, which developed a science coordination plan to identify and prioritize research activities on avian-solar interactions.[126]

Given that this topic sits at the intersection of two industries, collaborative teams are encouraged to include the necessary stakeholders and resources. To facilitate team formation, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List. SETO encourages applicants in this topic area to find potential partners on that list. Learn more in Section I.A.v.

Teams should consider including convening organizations, agricultural enterprises, governing bodies, local community organizations, solar developers, technology developers, trade associations, private-sector facilitators, and other key stakeholders where appropriate. Projects that test regional and nationwide approaches for the benefit of small- to mid-size agricultural enterprises, as well as projects that involve and benefit underrepresented communities, are of particular interest.

All projects should be ambitious but achievable and define 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. Applications should explicitly present the targeted system performance for the solar and agricultural sections of the proposal. The types of entities needed to replicate the project should be identified in the application, but specific partners can be identified once the project is underway.

Areas of Interest

Project proposals may address more than one of the areas listed below.

System Design and Technology Development

This area is focused on new system designs and technologies that may include novel mounting and racking designs or site configurations. The primary goal is improved

[125] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/seto-fy2019-balance-systems-soft-cost-reduction

[126] http://blmsolar.anl.gov/program/avian-solar/docs/Final_Avian-Solar_Science_Coordination_Plan.pdf. The utility-scale PV industry, environmental organizations, and academics convened a separate working group, the Avian Solar Working Group, which also developed a research questions framework. Ibid 119: https://www.researchgate.net/profile/Greg_Barron-Gafford/publication/335583033_Agrivoltaics_provide_mutual_benefits_across_the_food-energy-water_nexus_in_drylands/links/5da87eda4585159bc3d5a0e7/Agrivoltaics-provide-mutual-benefits-across-the-food-energy-water-nexus-in-drylands.pdf?origin=publication_detail

optimization of the combined solar and agricultural system, rather than utilizing components and designs developed for solar-only or agriculture-only sites. Applications in this area should explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions. They should also include a preliminary comparative cost-and-value analysis relative to the current state of the art. Applicants should address considerations such as support material usage, clearance for agricultural equipment, foundation designs, and cable management. Applicants should consider O&M implications of their solutions, including approaches to mitigate potential challenges.

Projects may include but are not limited to solutions that enable:

- Co-location with crop production primarily focused on food and feed crops. For example, combined system designs for solar generation and production of vegetables, fruit and/or grains.
- Co-location with livestock production primarily focused on pasture or range models. For example, combined system designs for solar generation and raising cattle, sheep, hogs, and poultry.
- Improved agricultural performance, including systems that enhance pollinator habitats, assist in water management or mitigate erosion losses, or improve crop production.
- Improved avian species interactions with solar-agriculture sites. For example, designs that facilitate safe nesting.
- Use of non-arable or low-production land, including field margins, flood-prone acreage, or runoff areas.

New Frameworks for Integrating Solar and Agriculture

Co-location of solar and agriculture opens new opportunities for innovative frameworks to increase land productivity and improve farmer livelihood. This area of interest supports research and analysis to develop innovative co-location models that help overcome soft cost barriers and realize additional value streams. Projects may include stakeholder processes to collect and analyze data that can inform the development of best practices and decision tools; provision of technical assistance and analytical support from national laboratories or other qualified subject matter experts to address local challenges; and development of plans and road maps to streamline processes and bring solutions to scale. Applicants may consider both active agriculture and conservation/remediation efforts, and may consider leveraging federal and state programs. While a pilot of an innovative model within a single agricultural enterprise is not of interest, a project may involve testing a new framework in pilot locations, assessing the results, and then replicating successful outcomes in other areas. Applicants should consider the role of data collection, analysis, and dissemination when developing their projects. Projects should include a clear path to testing the scalability and/or replicability of the framework(s), including a plan to sustain and scale those activities post-award.

Areas of interest include but are not limited to:

- Determining the potential value of diversified land use and revenue sources for agricultural enterprises
- Ownership structures that allow farmers to capture the value of solar on agricultural land
- Identifying and mitigating major barriers in information or sources of uncertainty at the nexus of solar and agriculture
- Compatibility and value assessment of system and site design with conservation or remediation programs—for example, the U.S. Department of Agriculture's Conservation Reserve Program.[127]
- Siting and zoning best practices for solar and agriculture co-location.

Research on Ecological and Performance Impacts of Co-Location

Applications to this area should support research and analysis on the ecological and/or performance impacts of solar and agriculture co-location, such as food production, water supply, soil resources, solar system energy production, and avian species. Projects may involve field research and the development or improvement of models or tools to quantify impacts and maximize benefits of solar and agriculture co-location.

Applications should clearly discuss the ecological impact or impacts to be studied, how the project builds upon current literature and state of knowledge, the data collection and experimental methodology to be used, and how this research will advance solar-agriculture co-location. Projects must be designed to produce results within the project period of performance.

Areas of interest include but are not limited to:

- Research to quantify the ecological benefits and costs of solar-agriculture co-location and identify strategies to maximize benefits
- Research to understand and minimize impacts on birds at solar-agriculture sites, including sites with crops, pollinator habitat, and/or native plants
- Research and analysis of performance of solar panels co-located with agriculture or pollinator habitat

Applications Specifically Not of Interest:
Applications will be deemed nonresponsive and declined without external merit review if they:

[127] U.S. Department of Agriculture Conservation Reserve Program. https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/

- Use only currently available solar energy technologies and hardware without clear differentiation in system components or operation, except where the primary project objectives are to research ecological or performance impacts
- Propose small, potentially off-grid systems with limited impact on land usage (i.e., solar water pumps or solar ventilation)
- Use low-temperature (under 100°C) direct solar thermal energy

vii. Topic Area 7: Artificial Intelligence Applications in Solar Energy with Emphasis on Machine Learning

This topic area will leverage the substantial AI-related know-how developed in the United States to develop disruptive solutions across the value chain of the solar industry. These projects will form partnerships between experts in AI and industry stakeholders, such as solar power plant operators or owners, electric utilities, PV module manufacturers, and others that can supply the necessary data as well as solar-related subject matter expertise.

Background

AI is the computer science and engineering field that develops computer systems that can perform tasks that ordinarily require human reasoning or expertise. Machine learning is a subfield of AI that develops methods by which computers can learn to perform tasks without programming by a human, such as classifying inputs or predicting unknown variables, by exposure to example data. For instance, if given a large number of examples of handwritten numbers and letters, a machine-learning model can be trained to recognize handwriting and convert it into digital text.[128] Another subfield of AI, expert systems, relies on encoded facts and rules of inference that enable computers to emulate human experts. AI techniques allow computers to make many fast decisions beyond human capabilities. AI can be used to classify input data into labeled categories, find optimal solutions to complicated mathematical problems, forecast the behavior of chaotic systems, and control devices in response to external stimuli.

In recent years, advanced AI techniques have been successfully applied to language translation,[129] voice recognition,[130] and strategy games such as Go.[131] In 2018, 466 AI

[128] MNIST Database: https://en.wikipedia.org/wiki/MNIST_database
[129] "Deep Learning Boosts Google Translate Tool." *Nature.* Davide Castelvecchi. September 27, 2016. https://www.nature.com/news/deep-learning-boosts-google-translate-tool-1.20696
[130] "Google Voice Search: Faster and More Accurate." Google AI Blog. September 24, 2015. https://ai.googleblog.com/2015/09/google-voice-search-faster-and-more.html
[131] DeepMind: AlphaGo. https://deepmind.com/research/case-studies/alphago-the-story-so-far

startups attracted over $9 billion in venture capital funding.[132] There are many AI applications that can impact the solar industry value chain. SETO has funded projects that have used or are using machine-learning methods. For example, solar forecasting[133] [134] [135] applications have been used to better predict solar generation, while control optimization technologies[136] [137] have been used to better manage electricity loads and better optimize the use of solar with building loads.[138] Still, there are numerous additional solar research areas where AI techniques, including machine learning, could enable substantial advancements by fully leveraging data sets generated by sensors, sensor networks, and stakeholders. Furthermore, the solar office solicits expertise from investigators with significant knowledge in the broader AI and machine-learning fields who may not have been exposed to the challenges facing the solar industry.

Applicants are expected to partner with solar industry stakeholders, such as solar power plant operators or owners, electric utilities and balancing authorities, EPC companies, PV module manufacturers, CSP component and subsystem suppliers, and others that can supply the necessary data as well as solar-related subject matter expertise. Applicants who need specific data to conduct work proposed in the application should demonstrate that the applicant already has access to that data or describe a clear path to acquiring access. Applicants are also strongly encouraged to describe how data generated during the project will adhere to FAIR guiding principles[139] for data access or why such adherence would not be feasible for their project. Examples of resources for best practices in open data policies can be found in the NSF DataOne program[140] or from the Center for Open Science.[141]

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[132] PwC | CB Insights MoneyTree™ Report Q4 2018: https://www.pwc.com/us/en/moneytree-report/moneytree-report-q4-2018.pdf

[133] Project profile: Watt-Sun: A Multi-Scale, Multi-Model, Machine-Learning Solar Forecasting Technology. https://www.energy.gov/eere/solar/watt-sun-multi-scale-multi-model-machine-learning-solar-forecasting-technology

[134] Project profile: University of California, San Diego. https://www.energy.gov/eere/solar/project-profile-university-california-san-diego-solar-forecasting-2

[135] Project profile: National Renewable Energy Laboratory. https://www.energy.gov/eere/solar/project-profile-national-renewable-energy-laboratory-1-solar-forecasting-2

[136] Project profile: National Renewable Energy Laboratory. https://www.energy.gov/eere/solar/project-profile-national-renewable-energy-laboratory-2-energise

[137] Grid Modernization Laboratory Consortium. https://gmlc.doe.gov/projects/1.5.01

[138] Project title: AI-Driven Smart Community Control for Accelerating PV Adoption and Enhancing Grid Resilience. https://www.energy.gov/eere/solar/solar-energy-technologies-office-lab-call-fy2019-21-systems-integration

[139] FAIR stands for Findable (e.g. indexed in a searchable resource), Accessible (e.g. via an open protocol), Interoperable (e.g. including references to qualified data and metadata), Reusable (e.g. released with a clear and accessible data usage license). For a more detailed treatment please see https://www.go-fair.org/fair-principles/

[140] https://www.dataone.org/

[141] https://cos.io/

To facilitate team formation, SETO is providing a forum where interested parties can add themselves to a Teaming Partner List. SETO encourages applicants in this topic area to find potential partners on that list. Learn more in Section I.A.v.

Since machine-learning-based techniques will need large amounts of data to train and test solutions, successful applicants will be required to assure that they will have access to the volume, type, and quality of data necessary to complete the project. To this end, collaborations or commercial relationships with organizations that generate or otherwise own rights to such data sets are strongly recommended.

Areas of Interest

Projects that leverage AI and machine-learning technologies but address issues covered explicitly by the other topics in this FOA should be submitted to the corresponding topic, not this one.

While the list of areas of interest below is not exhaustive, these solar industry-specific examples may provide insight to the AI community. SETO will examine compliant applications that respond to the spirit of this topic, unless they pertain to topics that have been explicitly deemed not of interest. All applicants should describe with references and quantitative metrics the current state of the art in the relevant space. In general, applications that seek to lower the levelized cost of solar-generated electricity should seek to develop and demonstrate a solution that will help achieve SETO's $0.03/kWh and $0.05/kWh cost targets for PV and CSP, respectively.[142] Applications that seek to lower the grid integration cost of high solar penetration should consult the respective examples for guidance.

Plant Performance Optimization and Reliability

Concentrating Solar-Thermal Power. CSP power plants use mirrors to concentrate sunlight on a receiver and convert it to heat, which can be used to generate electricity, be stored for use when most valuable, or provide other energy services. These systems involve a complex interaction of the solar field's thermal collection, management of dispatching storage or power generation, maintenance decisions to optimize production in consideration of productivity, reliability, and O&M cost. In central tower receiver plants, for example, the active assessment and control of heliostat performance is of paramount importance, as the real-time optimization of approximately 100,000 heliostats determines how much energy arrives at the receiver. An optimal operation requires that the input power to the system satisfies the plant operator's short- and long-term

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

objectives in terms of cost, efficiency, grid constraints, plant wear and tear, contractual agreements, etc. An AI-enabled platform could adaptively control the orientation, cleaning schedule, canting alignment, pointing accuracy, component-replacement timing, and other attributes of these heliostats covering nearly a square mile of land, while combining inputs from internal and external data sources, such as the temperature of the receiver, the power used to actuate the motors, short-term irradiance forecasting, wear-and-tear indicators, and others.

A similar platform could be used to dynamically adjust the various parameters for a large number of thermomechanical systems, including turbomachinery and thermal storage, in a CSP plant. These thermomechanical parameters can be adjusted to achieve technical and economic performance objectives, such as precise power output, how quickly a plant ramps up or down, optimal availability (i.e., high availability at a reasonable cost), and overall plant efficiency. An AI-enabled platform could calculate and apply those adjustments using sensor data, grid signals, or cost data as inputs for training and operation.

Successful applications will provide a brief analysis of and references to the state of the art and describe the benefits of the proposal in terms of the appropriate metric, such as the LCOE or the profitability of a plant. For reference, the office is seeking solutions that will reduce fixed O&M costs to $35/kW per year and variable O&M costs to $2.7/MWh, which correspond approximately to a 10% reduction relative to the 2030 targets.[143]

Photovoltaic Plants. PV plants can benefit by optimizing maintenance strategies using data from field equipment and environmental sources. While the cost of construction is the biggest single expense over the lifetime of a PV system, the system's long-term financial performance and resulting return on investment depends on achieving the expected energy yield while minimizing O&M expenses.

PV plant maintenance can be corrective—responding to events and conditions that negatively affect performance—or preventive, which can be scheduled on a recurring basis or on a prediction that certain performance-impacting conditions will happen in the near future. This prediction-based maintenance allows for optimal allocation of resources and could maximize the financial performance of the plant. It has long been proposed that by analyzing the signals captured from the sensors available in a plant, like irradiance, temperature, or power output, AI-based algorithms could detect the onset of significant or even catastrophic hardware problems and recommend the appropriate activity, such as a site visit or the procurement of replacement parts, to minimize costly disruption of operations.

[143] National Renewable Energy Laboratory. *The Potential Role of Concentrating Solar Power within the Context of DOE's 2030 Solar Cost Targets,* p. 78. Murphy, Caitlin, et. al. https://www.nrel.gov/docs/fy19osti/71912.pdf

Successful applications will provide a brief analysis of and references to the state of the art and describe the benefits of the proposal in terms of the appropriate metric, such as LCOE or the profitability of a plant. For reference, SETO is seeking projects that will enable reductions in the cost of annual maintenance to $3 to $4/kW per year.

Optimal Plant Design

PV systems must be designed to account for terrain, installation costs, orientation, power generation, reliability, and other metrics to optimize performance and cost. Using analysis of existing operations and performance records, as well as cost information, AI machine learning techniques could build relationships among the data sets associated with PV systems, including hardware specifications and its cost, maintenance records, and others in order to optimize design decisions based on a list of prioritized objectives such as minimum LCOE, maximum revenue from power, maximum self-consumption, resilience, or other goals.

SETO is interested in methods that rely mainly on machine learning and multi-objective optimization techniques to achieve desired designs. <u>Solutions that make heavy use of rules-based methods—i.e., expert systems—will be considered nonresponsive.</u> All proposals should provide a brief analysis of and references to the state of the art and describe the benefits of the proposal in terms of the appropriate metric, such as LCOE or plant profitability. Successful projects should exhibit a machine-learning-based solution that can improve the chosen metric by at least 10% compared to a state-of-the-art commercially available product.

Long-Term Performance and Reliability of PV Modules

A persistent challenge for the PV module industry is the prediction of the useful lifetime of new products based on accelerated-test and field-performance results. The direct path from material properties, module composition, and highly controlled accelerated test conditions to a confident prediction of the module's output 20, 30, or more years in future has been elusive. Current tests qualify modules to carry a stamp from a standards body but do not provide specific insight into the expected level of long-term performance. Machine-learning techniques could provide a quantifiable correlation among the long-term output of modules, the cumulative effect of factors such as temperature and radiation intensity and spectrum, and the material aspects of the module, such as components and manufacturing processes.

All applications should provide a brief analysis of the state of the art and describe the benefits of the proposal in terms of the appropriate metric, such as the correlation of the prediction with measured results. Successful projects will include a sustainable, non-DOE-funded plan for the validation of the methodology, such as by guaranteeing access to or collection of performance data from installed modules that can be used to validate the test and analysis methods the project develops.

Long-Term Insolation Prediction

Solar forecasting is an active field of research[144] with efforts targeting horizons from a few minutes to tens of hours. However, as more renewable resources are added to the grid and as resilience needs increase, the value of predicting solar energy output over multiple days will increase significantly. This capability could allow utilities that incorporate a lot of solar generation to procure enough energy reserves to allow continued service through rare but potentially critical events, such as four or more days of overcast weather with low winds.

All applications should provide a brief analysis of the state of the art and describe the benefits of the proposal in terms of the appropriate metric, such as the ability to improve forecast accuracy by reducing an appropriate metric, such as hourly root mean square error by at least 20% over an interval of at least three months, compared to predictions based on historical weather patterns.

Day-Ahead Net-Load Prediction

Utilities and balancing authorities have been developing load forecasting methods for more than four decades with state-of-the-art hourly day-ahead forecasts achieving 2% mean absolute percentage error[145] [146] (MAPE) relative to peak load. The increasing amount of behind-the-meter (BTM) solar PV in distribution networks has reduced the accuracy of the legacy algorithms[147] because of the variability of solar irradiance, which was not traditionally considered in the inputs, and the rapid increase in BTM solar installations, which was continuously changing the state of the electric distribution system and made the establishment of a baseline elusive.

SETO is interested in projects that will use AI, including machine learning, to achieve robust day-ahead forecasts of net-load in areas where BTM solar generates at least 20% of the annual energy demand. These forecasts should have a target accuracy of 2% hourly

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[144] U.S. Department of Energy Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-forecasting-2

[145] National Renewable Energy Laboratory. *The Value of Wind Power Forecasting.* Lew and Milligan. January 26, 2011. https://www.nrel.gov/docs/fy11osti/50814.pdf

[146] ERCOT. "Load Forecasting Overview." February 12, 2019. http://www.ercot.com/content/wcm/key_documents_lists/161457/10.1_Load_Forecasting_Overview.pdf

[147] *PJM Renewable Integration Study* Task Report, p. 26). 1992. https://www.pjm.com/~/media/committees-groups/subcommittees/irs/postings/pris-task3b-best-practices-from-other-markets-final-report.ashx

MAPE when averaged over all valid hours during a minimum of six months and measured at the substation.

Successful applicants are expected to develop probabilistic forecasts and validate their models on the Solar Forecast Arbiter platform[148] (currently in advanced development). Successful applications will be supported by at least one distribution utility that will provide the data sets for training and validation.

Data Imputation for Network Situation Awareness

The state of the electric power system (e.g., the transmission or distribution networks) can be described by a vector that contains the voltage magnitude and the phase angle between voltage and current at every node—i.e., at every intersection of two or more circuit elements of the network. Knowledge of the system's state is necessary for assessing its operational conditions and to make any control decisions. Since it is impractical to measure voltage angles and magnitudes at every node, a state estimator algorithm is used to calculate those values based on the knowledge of the network topology and the conventional Supervisory Control and Data Acquisition (SCADA) measurements collected at a subset of all the nodes. In addition to steady-state information mentioned above, the dynamic characteristics are more and more important for grid operation. In principle, more and higher accuracy measurements make the estimator more robust. Phasor measurement units (PMU) have been used to provide high-quality measurements from transmission system nodes, and in April 2019 the DOE Office of Electricity awarded eight projects[149] seeking to leverage PMU data with big data and machine-learning technologies, and provide solutions that support the reliable and resilient operation of the electric grid.[150]

Even with multiple sensors on the electric grid from smart meters and solar inverters as well as SCADA and PMU, the collected data is rarely complete or synchronized. Especially for the distribution networks, data is captured in fewer locations than the number necessary to provide a highly accurate state estimate and other critical situational awareness tools. This lack of situational awareness could have significant impact on solar PV operations and penetration levels. Typically, variable solar generation may restrict the integration of PV power plants in the transmission grids. Lack of system observability, or the ability to determine the state of the system, may push the operations of the distribution grid toward inefficiencies like unnecessary curtailment of solar. Limited

[148] Solar Forecast Arbiter: https://solarforecastarbiter.org
[149] U.S. Department of Energy Solar Energy Technologies Office. "Department of Energy Announces $20 Million for Artificial Intelligence Research." April 17, 2019. https://www.energy.gov/articles/department-energy-announces-20-million-artificial-intelligence-research
[150] FedConnect. Search for title DE-FOA-0001861: https://www.fedconnect.net/FedConnect/PublicPages/PublicSearch/Public_Opportunities.aspx

system observability may also lead to overly conservative estimation of the capacity to host distributed solar power generation.

SETO is interested in algorithms that use machine-learning techniques to synchronize and integrate different time series of electric network data from disparate sources and make decisions about selecting or imputing values where the sources are providing conflicting, erroneous, or no information. The projects should clearly demonstrate how these algorithms are integrated into solutions that improve the ability of the grid to allow high penetrations of solar with improved operational reliability compared to the state of the art, which should be described in the application. Projects should include individual and/or aggregation of sensor data and other information as direct measurements, data cloud systems, or non-utility-owned data. Projects should integrate multiple time-series sets of data into one consistent and accurate real-time data set to enhance the situational awareness for grid operations and planning tools. Projects should describe the sources of the data to be used and provide letters of support from their respective contributors.

Applications Specifically Not of Interest
Applications will be deemed nonresponsive and declined without external merit review if they:

- Propose novel CSP collector designs
- Propose siting for utility-scale solar
- Propose automated design of residential systems
- Propose new materials for PV cells
- Propose new PV cell structures
- Propose active process control for PV manufacturing
- Propose digital assistants or chat-bots
- Primarily focus on standards development
- Aim to achieve the goals of other topic areas in this FOA. Applications of AI that achieve the aims of other topic areas should be directed to the appropriate topic areas. Duplicative applications will be deemed nonresponsive.

viii. Topic Area 8: Small Innovative Projects in Solar (SIPS): PV and CSP

This topic area will use an abbreviated application process, described in Section IV of this FOA. Applicants are required to submit an LOI, but Concept Papers are not required.

Application Submission Note: The topic areas for this FOA have separate EERE Exchange entries to accommodate their different timelines and application requirements. Applicants to Topic Area 8: Small Innovative Projects in Solar (SIPS) will submit their application materials at the DE-TA8-0002243 FOA link: https://eere-exchange.energy.gov/Default.aspx#FoaId14079b45-f924-4ab9-b543-9283ee4ffade

Projects in this topic area will focus on innovative and novel ideas in PV or CSP that are riskier than research ideas based on established technologies.

All applications must describe the following:

1. The current understanding of the novel science, technology, concept, or component
2. The change to the state of the art if the research is successful and how it will reduce the LCOE of CSP or PV technologies
3. The new scientific or engineering understanding of the technology, concept, or component that will result from the project
4. The next appropriate research or development effort if the project is fully successful—for example, a prototype at a specific scale, component integration, a specified testing plan, or commercial integration

Topic Area 8.1: Small Innovative Projects in Solar (SIPS): PV

SIPS are high-risk, single-year projects in new and emerging areas of research focused on improving the power conversion efficiency, fielded energy output, service lifetime, and manufacturability of PV technologies. Designed to push the limits of PV technologies while making solar more affordable, this topic area calls for targeted, well-defined projects that can produce significant results within the first year of performance and, if successful, lay the foundation for continued research. PV SIPS projects should gain evidence through physical proofs of concept, modeling, or theoretical studies to justify or redirect future applied-research in the proposed area. Projects may address PV technologies at the system or component level. SETO is primarily interested in SIPS from novel and emerging areas of PV research that could produce dramatic progress toward lowering solar LCOE, targeting $0.02 per kWh for these projects. There are multiple pathways to achieve this goal, and one potential scenario is shown in Figure 16, below. Successful applicants will have a strong team, have a powerful argument for why their approach will be impactful, identify key metrics and baselines that clearly demonstrate how the proposal will surpass the state of the art, and name potential partners to help advance their project upon its completion. Projects led by principal investigators who have never or rarely participated in SETO's PV subprogram are of particular interest.

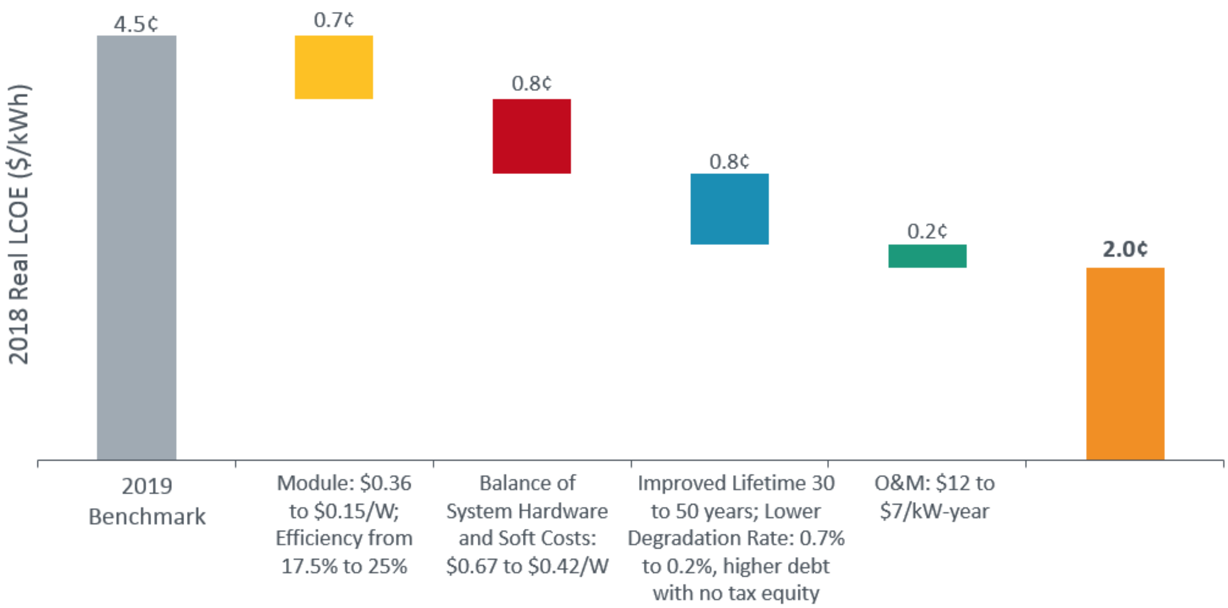

Figure 16. *Sample scenario for reducing costs to $0.02 per kWh for utility-scale systems*

Areas of Interest
Projects that fit the scope and duration of a PV SIPS project described above, which support an installed cost of solar of $0.02 per kWh by addressing the technical challenges described in Topic Area 1: Photovoltaics Hardware Research.

Applications Specifically Not of Interest
Applications will be deemed nonresponsive and declined without external merit review if they:

- Do not describe how they resolve the uncertainties of new concepts
- Are not designed to produce results in one year
- Do not sufficiently justify how the work will benefit the U.S. solar industry

Topic Area 8.2 Small Innovative Projects in Solar (SIPS): CSP

SETO intends to fund high-risk, focused projects that can quickly validate novel concepts in CSP technologies to support dramatic progress toward the CSP 2030 LCOE goal of $0.05 per kWh for baseload power or $0.02 per kWh for solar-thermal industrial process heat (SIPH).[151] All aspects of CSP plants with thermal energy storage, as well as SIPH innovations, are of interest. Ideas aligned with the goals of previous SETO CSP

[151] $0.02 per kWh is applicable for high-temperature applications above 600°C. $0.01 per kWh is needed for relevance in low-temperature applications of 100-200°C. Both must account for thermal energy storage.

solicitations are encouraged.[152] Broadly, ideas may fall into two categories: early efforts to apply novel science and ideas to CSP or SIPH, and innovative methods that close a technical gap or limitation in an emerging CSP or SIPH technology, concept, or component.

To help focus the tasks of these agile research efforts, the application introduction should describe a central hypothesis the project is testing. The explanation of the proposed work should clearly lay out a research plan that will be able to strongly support or disprove the key hypothesis. If successful, the technology should be positioned to move to the next stage of research and development, whether that's fabrication of a prototype, integration within a system, an expansive testing regime, commercial integration, other technology development activity, or some combination in a broader research effort. Applicants should demonstrate an understanding of the major issues impeding their technical approach and identify the barrier(s) that their research effort will target. Applicants must demonstrate awareness of similar approaches and previous relevant research on the proposed technology, concept, or component. Potentially relevant work funded previously funded by SETO can be found on the EERE website.[153]

Areas of Interest

This list is not exhaustive. Applications that address areas not listed here will be considered for funding if they address the broader goals of Topic Area 8.2.

- Novel high-temperature (greater than 700°C) receiver concepts or material systems for gas, particle, or liquid heat-transfer media that have the potential to tolerate daily thermal cycling and be readily scaled and integrated with commercial-scale CSP plants
- Novel heliostat operations and/or maintenance optimization via software tools, hardware, or other methods
- High-heat-transfer coefficient particle–to–sCO_2 heat exchangers appropriate for Generation 3 CSP systems. The impact of heat exchanger cost ($\$/kW_{th}$), heat

[152] Examples include:
CSP: APOLLO: https://energy.gov/eere/solar/funding-opportunity-announcement-concentrating-solar-power-advanced-projects-offering-low
CSP COLLECTS: https://energy.gov/eere/solar/funding-opportunity-announcement-csp-concentrating-optics-lower-levelized-energy-costs
Solar Desalination: https://energy.gov/eere/solar/funding-opportunity-announcement-solar-desalination
Generation 3 CSP: https://energy.gov/eere/solar/funding-opportunity-announcement-generation-3-concentrating-solar-power-systems-gen3csp
SETO FY2018 FOA Topic 2: https://energy.gov/eere/solar/funding-opportunity-announcement-fy-2018-solar-energy-technologies-office
SETO FY2019 FOA Topic 2: https://energy.gov/eere/solar/funding-opportunity-announcement-solar-energy-technologies-office-fiscal-year-2019
[153] Concentrating Solar Power Competitive Awards. https://www.energy.gov/eere/solar/concentrating-solar-power-competitive-awards

transfer coefficient (watts per square meter per Kelvin), approach temperature (difference expressed in Kelvin), and secondary impact on system parasitics and energy loses (kW_e and kW_{th}) should be accounted for to show a dramatic improvement on the performance and cost of a particle system[154] or a system with indirect particle storage.[155]

- Innovations that improve the efficiency and operable temperature range of compressors for sCO_2 Brayton power cycles by increasing the amount of liquid CO_2 that's acceptable in the compressor inlet. Because the temperature-pressure relationship of CO_2 changes rapidly around the critical temperature of 31°C, sCO_2 compressors run the risk of generating liquid CO_2, which can damage equipment. Innovations that increase the range of allowable inlet pressure over a broad range of compressor-inlet and ambient-air-temperature conditions can help system designers optimize cycle efficiency when coupled with dry cooling, which transfers waste heat to the environment without using water.

Applications Specifically Not of Interest
Applications will be deemed nonresponsive and declined without external merit review if they:

- Contain concepts that are inconsistent with a minimum 30-year lifetime of a CSP plant, although cost-effective replacement may be an acceptable strategy

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, i.e., applications that that violate 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).

[154] Sandia National Laboratories. *Parametric Analysis of Particle CSP System Performance and Cost to Intrinsic Particle Properties and Operating Conditions.* Albrecht, Kevin J., Matthew L. Bauer, and Clifford K. Ho. https://energy.sandia.gov/wp-content/uploads/dlm_uploads/2019/misc/08/G3P3/ES2019_3893-Albrecht.pdf

[155] National Renewable Energy Laboratory. *Concentrating Solar Power Gen3 Demonstration Roadmap*. Mehos, Mark, Turchi, Craig, Vidal, Judith, Wagner, Michael, Ma, Zhiwen, Ho, Clifford, Kolb, William, Andraka, Charles, and Kruizenga, Alan. https://www.osti.gov/biblio/1338899

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 approximately $125.5 million of federal funding available for new awards under this FOA, subject to the availability of appropriated funds. EERE anticipates making approximately 56 to 80 awards under this FOA. EERE may issue one, multiple, or no awards. Individual awards may vary between $300,000 and $39 million.

EERE may issue awards in one, multiple, or none of the following topic areas. Applications above the maximum value listed may not be considered. The below estimates are listed for topic areas as a whole.

	Topic Title	Technology Readiness Level (TRL) and Cost Share	Details (topic funding and award numbers are approximate)
1	Photovoltaics Hardware Research	TRL 2 to 6; 20-50% Cost Share	$15 million total $1 million to $2 million per award 3 to 4 years per award 8 to 12 awards
2	Integrated Thermal Energy STorage and Brayton Cycle (Integrated TESTBED)	TRL 4-7; 20-50% Cost Share	$39 million total $19.5 million to $39 million per award 3 to 5 years per award 1 to 2 awards
3	Solar Energy Evolution and Diffusion Studies 3 (SEEDS 3)	NA 20% Cost Share	$10 million total $1 million to $2 million per award 1 to 3 years per award 6 to 8 awards
4	Innovations in Manufacturing: Hardware Incubator	TRL 2-6; 20-50% Cost Share	$14 million total $1 million to $2 million per award 1 to 3 years per award 7 to 9 awards

5	Systems Integration	TRL 2-6; 20-50% Cost Share	$30 million total $2 million to $4 million per award 1 to 3 years per award 7 to 11 awards
6	Solar and Agriculture: System Design, Value Frameworks and Impacts Analysis	TRL 2-6; 20-50% Cost Share	$6.5 million total $1 million to $2 million per award 1 to 3 years per award 4 to 6 awards
7	Artificial Intelligence Applications in Solar Energy with Emphasis on Machine Learning	TRL 2-6; 20-50% Cost Share	$6 million total $500,000 to $750,000 per award 1 to 3 years per award 8 to 12 awards
8	Small Innovative Projects in Solar (SIPS): PV and CSP	TRL 2-6; 20% Cost Share	$5 million total $300,000 per award 1 year per award 15 to 20 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.

ii. 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.

iii. 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. 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 (M&O) 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 Areas 1 and 8 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 Area 1: Photovoltaics Hardware Research and Topic Area 8: Small Innovative Projects in Solar (SIPS): PV and CSP. For Topic Areas 1 and 8, 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. The requirement for the prime recipient's share of total project costs can be met with the prime's percentage being greater than the individual contribution of each subrecipient even if the prime applicant's share is less than 50% of the scope of work. For example a project allocation of 40% prime applicant and three subapplicants each utilizing 20% of the budget is allowable.

Topic Area 4 Eligibility Restriction: Eligibility is restricted to for-profit entities as the prime recipient of awards under Topic Area 4: Innovations in Manufacturing: Hardware Incubator. The reason for this restriction is that SETO believes for-profit entities are the entities most likely to achieve the topic's required objectives, as they are the only entities with the capacity to rapidly commercialize new technologies related to innovations in manufacturing. For Topic Area 4, 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. The requirement for the prime recipient's share of total project costs can be met with the prime's percentage being greater than the individual contribution of each subrecipient even if the prime applicant's share is less than 50% of the scope of work. For example a project allocation of 40% prime applicant and three subapplicants each utilizing 20% of the budget is allowable.

A. Eligible Applicants

i. Individuals

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

ii. 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 Areas 1, 4, and 8, 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.

iii. 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.

iv. 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.

v. 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 Topic Areas 1, 2, 4, 5, 6, and 7, but may not be possible or applicable, depending on the technology, technology readiness level,[156] or current regulations and market structures.

	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)
Projects *with* a mixture of demonstration and R&D activities throughout all Budget Periods	Research and development tasks (20% cost share) and demonstration tasks (50% cost share) clearly delineated and marked appropriately		

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 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.

156 See Appendix F for further discussion of technology readiness levels.

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
- Costs of software licenses. Costs for the purchase of off-the-shelf software offered commercially to the general public will be considered on a case-by-case basis. Third party donation of off-the-shelf software will be considered on a case-by-case basis. Software licenses for software owned by prime or sub-recipients will not be considered allowable as cost share.

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, Topic Area 8 SIPS Applications, and Replies to Reviewer Comments (Topic Areas 1-7) 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, Topic Area 8 SIPS Applications and Replies to Reviewer Comments (Topic Areas 1-7) 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

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.

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.

Full Applications (Topic Areas 1-7)

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.

Topic Area 8 SIPS Applications

Topic Area 8 SIPS Applications are deemed compliant if:

- The applicant submitted a compliant LOI
- The Topic Area 8 SIPS Application complies with the content and form requirements in Section IV.E 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.

Replies to Reviewer Comments (Topic Areas 1-7)

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 notification that reviewer comments are available for review.

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 Areas 1, 4, and 8, as described in Section III, Eligibility Information, 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:

1. *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.

2. *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.

3. *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.

4. *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.

5. *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.

6. *Limit on FFRDC Effort*
See eligibility restriction for Topic Areas 1, 4, and 8 in Section III, Eligibility Information.

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

An entity may submit more than one LOI, Concept Paper, Topic Area 8 SIPS Application, and Full Application to this FOA, provided that each application describes a unique, scientifically distinct project and provided that an eligible LOI was submitted for each Topic Area 8 SIPS Application and 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 for Full Applications will include three phases: an LOI phase, Concept Paper phase, and a Full Application phase. The application process for Topic Area 8 SIPS will include two phases: an LOI phase and a SIPS Application phase. **Only applicants who have submitted an LOI will be eligible to submit a Topic Area 8 SIPS Application, and 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 for Topic Areas 1-7, Topic Area 8 SIPS 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 for all applications except SIPS applications. For SIPS applications, additional reference pages are permitted beyond the page limit;
- 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, Topic Area 8 SIPS Applications, and Full Applications for Topic Areas 1-7 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, Topic Area 8 SIPS Application, Full Application for Topic Areas 1-7, or Reply to Reviewer Comments. Once the LOI, Concept Paper, Topic Area 8 SIPS Application, Full Application for Topic Areas 1-7, 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, Topic Area 8 SIPS Application, Full Application for Topic Areas 1-7, or Reply to Reviewer Comments before the applicable deadline.

  EERE urges applicants to carefully review their LOI, Concept Papers, Topic Area 8 SIPS Application, and Full Applications and to allow sufficient time for the submission of required information and documents. All Topic Area 8 SIPS Applications and Full Applications for Topic Areas 1-7 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 who 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.

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.

Application Submission Note: The topic areas for this FOA have separate EERE Exchange entries to accommodate their different timelines and application requirements.

- Applicants to Topic Areas 1, 3, 4, 5, 6, and 7 will submit their application materials at the DE-FOA-0002243 FOA link: https://eere-exchange.energy.gov/default.aspx#FoaIdc8e280d2-b7bf-4138-810b-cad9ba1541ac
- Applicants to Topic Area 2: Integrated Thermal Energy STorage and Brayton Cycle (Integrated TESTBED) will submit their application materials at the DE-TA2-0002243 FOA link: https://eere-exchange.energy.gov/Default.aspx#FoaId9d6ec5e2-0080-446d-b52b-df2988138b0c
- Applicants to Topic Area 8: Small Innovative Projects in Solar (SIPS) will submit their application materials at the DE-TA8-0002243 FOA link: https://eere-exchange.energy.gov/Default.aspx#FoaId14079b45-f924-4ab9-b543-9283ee4ffade

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 Topic Area 8 SIPS Application, or a Concept Paper and Full Application for Topic Areas 1-7, 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, Eligibility Information).

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;
- Whether the applicant has applied to a FOA managed by SETO in the last 5 years;
- How the applicant heard about the funding opportunity (SETO newsletter, SETO website, Twitter, Facebook, news article, word of mouth, other);
- 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 for Topics 1-7, 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, Impacts and Addendum	4 pages maximum (10 pages maximum for Topic Area 2)	Applicants are required to describe succinctly: • The proposed technology, including its basic operating principles and how it is unique and innovative; • The proposed technology's target level of performance (applicants should provide technical data or other support to show how the proposed target could be met); • The current state of the art in the relevant field and application, including key shortcomings, limitations, and challenges; • How the proposed technology will overcome the shortcomings, limitations, and challenges in the relevant field and application; • The potential impact that the proposed project would have on the relevant field and application; • The key technical risks/issues associated with the proposed technology development plan; and • The impact that 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 8: Small Innovative Projects in Solar (SIPS): PV and CSP

Applicants must submit a SIPS Application by the specified due date and time to be considered for funding under Topic Area 8 of this FOA.

i. SIPS Application Content Requirements

Applicants to Topic Area 8: SIPS must submit a mandatory LOI. 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:

Submission	Components	File Name
SIPS Application (PDF, unless stated otherwise)	Technical Volume (PDF format. See table below for notes on content.) 1 page cover page + 4-page content limit	ControlNumber_LeadOrganization_Technical Volume
	Summary Slide that is Public Release Ready (Microsoft PowerPoint format. 1 page limit)	ControlNumber_LeadOrganization_Slide
	SF-424 Application for Federal Assistance (PDF format)	ControlNumber_LeadOrganization_App424
	SF-LLL Disclosure of Lobbying Activities (PDF format)	ControlNumber_LeadOrganization_SF-LLL
Please note these documents will be required at such time the application is selected for negotiations of an award	Budget Justification (Microsoft Excel format. Applicants must use the template available in EERE Exchange)	ControlNumber_LeadOrganization_Budget_Justification
	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
	Foreign Entity and Foreign Work waiver requests, if applicable (PDF format)	ControlNumber_LeadOrganization_Waiver

<table>
<tr><th>SIPS Application Technical Volume Section</th><th>Description</th></tr>
<tr><td>Cover Page
[1 Page Max]</td><td>Project Title
The specific FOA Topic Area being addressed and Project Focus Area(s): e.g., Photovoltaics, CdTe deposition, Reliability, CSP, Receivers
(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</td></tr>
<tr><td>Project Description
[4 Pages Max]</td><td>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.
An unlimited number of reference pages, one-page letters of support and/or one-page resumes of project participants may be submitted but are not required.</td></tr>
</table>

Summary Slide (Public Release ready) [Not included in page limit]	There is a PowerPoint 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 content of this Summary Slide must not include any proprietary or sensitive business information as DOE may make it available to the public after selections are made. 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 for the Full Application for Topic Areas 1-7

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 (50-page limit for Topic Area 2)	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 Foreign Work waiver requests, if applicable (PDF format)	ControlNumber_LeadOrganization_Waiver
	U.S. Manufacturing Plan (PDF format) (except for Topic Areas 3 and 8)	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 for Topic Areas 1-7 **except Topic Area 2** 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.

For Topic Area 2, the technical volume may not be more than 50 pages, including the information listed above, and applicants should include all information requested in the Topic Area 2 description, in Section I.B.ii, above.

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	Provide a succinct description of the specific activities to be conducted over the proposed period of performance. Descriptions should contain enough detail to

Project Objectives (SOPO)	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. Projects with a mixture of R&D and demonstration activities (with corresponding recipient cost share) should clearly delineate the proposed cost share for each activity or task. • (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.

<table>
<tr><td></td><td>(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:</td></tr>
<tr><td>Team Qualifications and Resources</td><td>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</td></tr>
<tr><td>Appendices</td><td>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.</td></tr>
</table>

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 http://energy.gov/management/office-management/operational-management/financial-assistance/financial-assistance-forms, under Certifications and Assurances. 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 Foreign Work (if applicable)

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.

Performance of Work in the United States (Foreign Work Waiver)

As set forth below, 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 foreign work waiver request.

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 Areas 3 and 8. 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 Topic Areas 3 and 8, 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 for Topic Areas 1-7 and all eligible Topic Area 8 SIPS applications. Applicants to Topic Area 1-7 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. Topic Area 8 applicants will not be able to submit a Reply to Reviewer Comments. 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 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 (five pages for Topic Area 2), EERE will review only the first three pages (or first five for Topic Area 2) and disregard any additional pages.

SECTION	PAGE LIMIT	DESCRIPTION
Text	Three (3) pages for all Topic Areas other than 2 and 8 Five (5) pages for Topic Area 2	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

LOIs, Concept Papers, Topic Area 8 SIPS Applications, Full Applications for Topic Areas 1-7, and Replies to Reviewer Comments (Topic Areas 1-7) 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 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. **National Environmental Policy Act (NEPA) Requirements Related to Pre-Award Costs**
   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 pre-award costs incurred prior to receiving written authorization from the Contracting Officer. If the applicant elects to undertake activities that DOE determines 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 for their project 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. 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.

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

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 foreign work waiver, the applicant must submit a written waiver request to EERE. Appendix C lists the necessary information that must be included in a request for a foreign work waiver.

   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.

As appropriate and to the extent consistent with law, applicants shall ensure that, to the greatest extent practicable, iron, aluminum, steel, cement, and other manufactured products used in the proposed project are produced in the United States. This includes items and construction materials composed entirely or partially of non-ferrous metals such as aluminum; plastics and polymer-based products such as polyvinyl chloride pipe; aggregates such as concrete; glass, including optical fiber; and lumber. This requirement shall flow down to all sub-awards, including all contracts, subcontracts, and purchase orders for work performed under the proposed project.

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 of 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 (Topic Areas 1-7) and Topic Area 8 SIPS Applications

Full and SIPS Applications (Topic Area 8) 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. For topics 3.1, 3.2, and 7, the application includes sufficient explanation of how project-generated data will be made available to researchers and other stakeholders.

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 (Topic Areas 1-7)

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
- The degree to which the project improves resiliency of critical infrastructure
- Whether the proposed project will occur in a Qualified Opportunity Zone or otherwise advance the goals of Qualified Opportunity Zones[157]. The goals include spurring economic development and job creation in distressed communities throughout the United States.

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

[157] Opportunity zones were added to the Internal Revenue Code by section 13823 of the Tax Cuts and Jobs Act of 2017, codified at 26 U.S.C. 1400Z-1. The list of designated Qualified Opportunity Zones can be found in IRS Notices 2018-48 (PDF) and 2019-42 (PDF). Further, a visual map of the census tracts designated as Qualified Opportunity Zones may also be found at Opportunity Zones Resources. Also see, frequently asked questions about Qualified Opportunity Zones.

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, Topic Area 8 SIPS Applications and Full Applications (Topic Areas 1-7) 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 (Topic Areas 1-7)

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 and Topic Area 8 SIPS Applications 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 or Topic Area 8 SIPS Application was selected for award negotiations. Alternatively, EERE may notify one or more applicants that a final selection determination on particular Full Applications or Topic Area 8 SIPS 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 Topic Areas 1-7 or Topic Area 8 SIPS 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 preaward 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 Topic Areas 1-7 or Topic Area 8 SIPS Application for federal funding in the future. A notification letter stating the Full Application for Topic Areas 1-7 or Topic Area 8 SIPS 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 Topic Areas 1-7 or Topic Area 8 SIPS 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:

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**.

DUNS Number

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

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.

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.

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, Full Applications for Topic Areas 1-7, and Topic Area 8 SIPS Applications will not be accepted through Grants.gov.

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.

C. 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.

i. Foreign National Access Under DOE Order 142.3A, "Unclassified Foreign Visits and Assignments Program"

All applicants selected for an award under this FOA may be required to provide information to DOE in order to satisfy requirements for foreign nationals' access to DOE sites, information, technologies, equipment, programs or personnel. A foreign national is defined as any person who is not a U.S. citizen by birth or naturalization. If a selected applicant (including any of its subrecipients, contractors or vendors) anticipates involving foreign nationals in the performance of its award, the selected applicant may be required to provide DOE with specific information about each foreign national to ensure compliance with the requirements for access approval. National laboratory personnel already cleared for site access may be excluded. Access approval for foreign nationals from countries identified on the U.S. Department of State's list of State Sponsors of Terrorism must receive final approval authority from the Secretary of Energy or the Secretary's assignee before they commence any work under the award.

ii. 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.

iii. 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.

iv. 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 recipient may be required to prepare the records and the costs to prepare the necessary records may be included as part of the project costs.

v. 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.

vi. 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.

vii. 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.

viii. 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.

ix. 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.

x. 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.

xi. 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.

xii. 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.

xiii. 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.

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

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. Applicants are advised to not include any critically sensitive proprietary detail.

If an application includes trade secrets or information that is commercial or financial, or information that is confidential or privileged, it is furnished to the Government in confidence with the understanding that the information shall be used or disclosed only for evaluation of the application. Such information will be withheld from public disclosure to the extent permitted by law, including the Freedom of Information Act. Without assuming any liability for inadvertent disclosure, EERE will seek to limit disclosure of such information to its employees and to outside reviewers when necessary for merit review of the application or as otherwise authorized by law. This restriction does not limit the Government's right to use the information if it is obtained from another source.

Concept Papers, Full Applications for Topic Areas 1-7, Topic Area 8 SIPS Applications, Replies to Reviewer Comments, and other submissions containing confidential, proprietary, or privileged information must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

The cover sheet of the Concept Paper, and Topic Area 8 SIPS Applications, Full Application, Reply to Reviewer Comments, or other submission must be marked as follows and identify the specific pages containing trade secrets, confidential, proprietary, or privileged information:

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

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

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. 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.

I. Retention of Submissions

EERE expects to retain copies of all LOI, Concept Papers, Full Applications for Topic Areas 1-7, Topic Area 8 SIPS 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.

J. 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 Areas 3 and 8. 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.

K. 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.

L. 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.

M. 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.

N. Export Control

The U.S. government regulates the transfer of information, commodities, technology, and software considered to be strategically important to the U.S. to protect national security, foreign policy, and economic interests without imposing undue regulatory burdens on legitimate international trade. There is a network of federal agencies and regulations that govern exports that are collectively referred to as "Export Controls." To ensure compliance with Export Controls, it is the prime recipient's responsibility to determine when its project activities trigger Export Controls and to ensure compliance.

Export Controls may apply to individual projects, depending on the nature of the tasks. When Export Controls apply, the recipient must take the appropriate steps to obtain any required governmental licenses, monitor and control access to restricted information, and safeguard all controlled materials. Under no circumstances may foreign entities (organizations, companies or persons) receive access to export controlled information unless proper export procedures have been satisfied and such access is authorized pursuant to law or regulation.

Applicants are advised that some of the results of the research conducted under this FOA are expected to be restricted for proprietary reasons and not published or shared broadly within the scientific community.

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 one informational webinar during the FOA process. 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 Country of incorporation; and the extent, if any, the entity is state-owned or -controlled;
   - 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 D – 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 E – 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 F – 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