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

SOLAR ENERGY TECHNOLOGIES OFFICE FISCAL YEAR 2021 FUNDING PROGRAM Photovoltaics and Concentrating Solar Power

Funding Opportunity Announcement (FOA) Number: DE-FOA-0002378
FOA Type: Initial
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FOA Issue Date:	3/25/2021
Submission Deadline for Letter of Intent:	All Topic Areas: 4/26/2021 5 p.m. ET
Submission Deadline for Concept Papers:	Topic Areas 1, 2, 3, 4: 4/27/2021 5 p.m. ET
Submission Deadline for Full Applications:	All Topic Areas: 6/24/2021 5 p.m. ET
Expected Submission Deadline for Replies to Reviewer Comments:	Topic Areas 1, 2, 3, 4: 7/27/2021 5 p.m. ET
Expected Date for EERE Selection Notifications:	9/24/2021
Expected Time Frame for Award Negotiations:	September 2021–January 2022

- **Topic Areas 1, 2, 3, 4a, 4b:** Applicants must submit a Letter of Intent and a Concept Paper by 5 p.m. ET on the due dates listed above to be eligible to submit a Full Application.
- **Topic Areas 5a, 5b:** Applicants must submit a Letter of Intent by 5 p.m. ET on the due date listed above to be eligible to submit a Full Application.
- To apply to this FOA, applicants must register with and submit application materials through EERE Exchange at https://eere-exchange.energy.gov, EERE's online application portal.
- Applicants must designate primary and backup points of contact in EERE Exchange with whom EERE will communicate to conduct award negotiations. If an application is selected for award negotiations, it is not a commitment to issue an award. It is imperative that the applicant/selectee be responsive during award negotiations and meet negotiation deadlines. Failure to do so may result in cancelation of further award negotiations and rescission of the selection.

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I. Funding Opportunity Description

A. Background and Context

i. Background 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) to invest in innovative research and development (R&D) that will drive down costs and develop next-generation technologies ready for commercialization. SETO works to accelerate the development and deployment of solar technology to support an equitable transition to a decarbonized electricity system by 2035 and a decarbonized energy sector by 2050. Achieving these goals will support the nationwide effort to meet the threat of climate change and ensure that all Americans benefit from the transition to a clean energy economy. The office supports solar energy research, development, demonstration, and technical assistance in five areas—photovoltaics (PV), concentrating solar-thermal power (CSP), systems integration, manufacturing and competitiveness, and soft costs—to improve the affordability, reliability, and domestic benefit of solar technologies on the electric grid.

Solar energy technologies are essential to achieving a 100% clean electricity system by 2035 and a net-zero energy system by 2050. The projects funded through this FOA will help further reduce costs for solar technologies, enable long-duration storage of solar energy, and develop technology for carbon-free industrial processes in the United States. This FOA complements the office's FY2021 Systems Integration and Hardware Incubator Funding Program, announced in December 2020, that will support projects that enable solar to connect reliably and securely to the nation's electric grid, while developing next-generation solar technologies and boosting U.S. solar manufacturing. In addition, SETO has several prize competitions underway that support American leadership in the clean energy economy.[1] In sum, SETO's support of innovative R&D will accelerate solar deployment and lower the costs to decarbonize our electricity grid.

A 100% clean electricity grid will look very different from the grid as it is today. By 2035, solar and wind may need to account for as much as 80% of electricity supply.[2] At the same time, more and more of America's energy demand will come from electricity as buildings, transportation, and industry are electrified. While this transition will face technical challenges, it will not succeed if communities of color and low-income communities are left out. Low-cost solar energy can help relieve energy burdens and provide clean, local electricity that can increase community resiliency across the country.

[1] Learn about SETO's open funding opportunities here: https://www.energy.gov/eere/solar/funding-opportunities

[2] Internal NREL analysis, using the ReEDS model.

Today, solar accounts for just 3% of U.S. electricity,[3] which means that to combat climate change, the nation's solar capacity would likely need to grow by hundreds of gigawatts (GW) in the next 15 years, with an annual rate of deployment three to five times higher than recent deployment rates.

Continued cost declines are critical to enabling the rapid deployment required to achieve this clean electricity goal. The cost of solar PV has decreased more than 80% since 2010, driven by global economies of scale, technology innovation, and greater confidence in PV technology. Figure 1, below, illustrates the declines in both levelized cost of energy (LCOE) benchmarks and actual power purchase agreement (PPA) prices for utility-scale PV systems. However, current costs are not low enough to drive rapid increases in solar deployment. Costs have more room to decline as operation and maintenance (O&M) of solar energy systems become more streamlined, financing costs are lowered, or more energy is delivered over a system's lifetime.

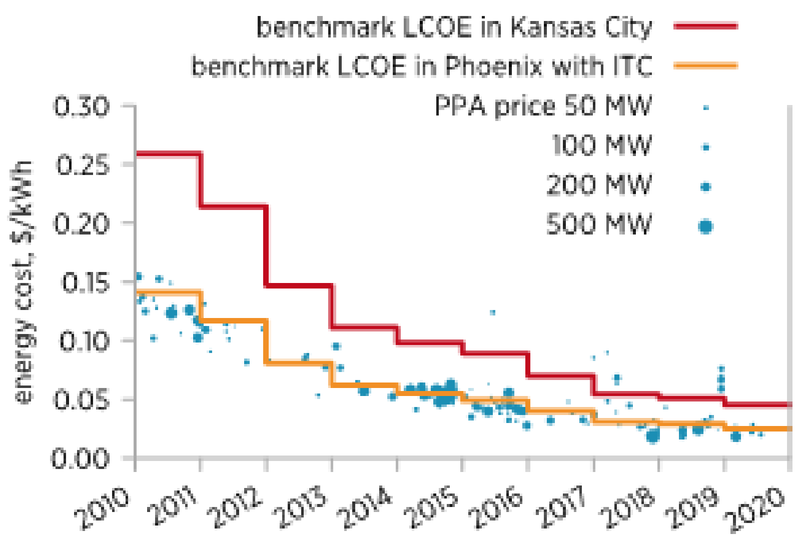

Figure 1. *The modeled cost (lines) and actual contracted energy price in power purchase agreements (PPA, circles) for utility-scale PV electricity have declined more than 80% since 2010. PPA prices and the orange line include incentives such as the investment tax credit and are often located in sunny areas.[4] The red line shows unsubsidized systems with average U.S. climate.*

While PV has dominated the U.S. solar market, with over 90 GW deployed by the end of 2020, CSP plants are another important solar technology. There are nearly 100 CSP plants in commercial operation worldwide, representing almost 7 GW of capacity. These projects serve as real-world laboratories for developing best practices and identifying priority areas for further technology development. Continued optimization of these

[3] EIA, Electricity Data Browser. Accessed August 25, 2020.
[4] M. Bolinger, J. Seel, D. Robson. "Utility-Scale Solar, 2019 Edition" (December 2019).

practices will improve the performance, reliability, and cost of future CSP plants, which have the potential to provide between 25 and 160 GW of U.S. capacity by 2050.[5]

Many CSP plants in operation today utilize thermal energy storage (TES) systems, which store solar energy as heat for use when it is needed. Energy storage technologies can help mitigate the variability of solar and provide additional grid support. While lithium-ion batteries have enabled rapid deployment of energy storage coupled with solar energy, most commercial applications have been limited to four hours of storage or less. Longer-term storage can help alleviate the impact of longer periods of cloudy weather, for example, or even seasonal variations of solar energy production. Existing CSP plants have already demonstrated long durations of daily storage, up to 15 hours, which increases their value to the grid. With integrated TES, CSP plants can produce consistent amounts of electricity on demand, regardless of the time of day or amount of cloud cover.

Achieving a net-zero carbon energy supply by 2050 will require the adoption of clean energy technologies in sectors beyond electricity generation. Even with more renewable electricity available, many industrial processes will be difficult to electrify because they require high temperatures or other process characteristics. CSP technologies can directly produce steam or high-temperature fluids by concentrating sunlight. This solar-generated heat can then be directly integrated with thermally driven industrial processes. Solar-thermal processes could also generate energy-dense chemicals or fuels that could deliver stored solar energy throughout the country and the world. Developing pathways for solar-derived chemicals or fuels can help reduce the carbon intensities of numerous industries. However, significant technological challenges remain, including the design and equipment for integrated solar-thermal processes that can address the variability challenges inherent in using sunlight as fuel.

Meanwhile, solar PV has been the fastest growing source of new electricity generation on the grid for the past two years, but to decarbonize electricity by 2035, it will need to grow three to five times faster than the current rate. It is likely that carbon-free grids will require long-duration storage technologies capable of storing and delivering 10 or more hours of electricity. Decarbonizing industrial processes and the entire energy sector by 2050 will require new technologies that can integrate solar energy with a wide variety of industrial processes.

The solar industry, which includes the research communities leading the way toward a clean energy economy, does not match the diversity of the United States.[6] Women and

[5] C. Murphy, Y. Sun, W. Cole, G. Maclaurin, C. Turchi, and M. Mehos. "The Potential Role of Concentrating Solar Power within the Context of DOE's 2030 Solar Cost Targets." 2019.

minorities are underrepresented in the solar industry and in the science, technology, engineering, and math (STEM) fields. STEM fields also lack diversity in geographical origin, with U.S. rural areas underrepresented relative to large population centers. Since STEM students and graduates support R&D activities in universities, National Laboratories, and private industry, the lack of diversity in that pipeline adversely affects the opportunities and potential outcomes in scientific and economic output. To achieve the administration's energy justice goals, SETO is working to ensure that the research it funds will support more equitable participation in the solar energy research community. To this end, SETO, recognizing the inherent advantages of diverse teams, requires applicants to this FOA to include a Diversity, Equity, and Inclusion Plan that describes proposed activities applicants will engage in to broaden participation from members of groups and institutions that are historically underrepresented in solar energy research.

In all, the investments made in this funding opportunity will help support U.S. technological leadership in solar, create equitable opportunities for American researchers and entrepreneurs, and advance technical solutions to combat global climate change.

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 to achieve 1 megawatt (MW) of production per year in 1980, located in California.[7] 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[8] and pioneered the development of molten salt in CSP plants, which is used as a blueprint for CSP plants around the world.

Since the announcement of the SunShot Initiative in 2011, SETO has been working to make solar electricity price-competitive with conventional utility sources.[9] Those investments have lowered costs across the solar value chain. 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

[6] SEIA: U.S. Solar Industry Diversity Study 2019.
[7] ARCO Solar built the first manufacturing line greater than 1 MW in the U.S. in 1979.
[8] Based on SETO analysis of the National Renewable Energy Laboratory's efficiency chart.
[9] SETO. *SunShot Vision Study*, 2012. https://www.energy.gov/sites/prod/files/2014/01/f7/47927.pdf.

American leadership in solar innovation and increase energy affordability across the country.[10]

In 2017, SETO announced that the industry achieved the SunShot 2020 utility-scale PV cost goal of $0.06 per kilowatt-hour (kWh), three years early and turned attention to meeting the 2030 cost target of $0.03 per kWh by 2030.[11] However, to meet the urgency of the climate crisis and accelerate solar deployment by three to five times, costs need to fall faster. Recognizing this need, SETO is accelerating this goal. The new target for unsubsidized LCOE for utility-scale PV at the point of grid connection[12] is $0.03/kWh by 2025 and $0.02/kWh by 2030.

Although these targets are aggressive, there are multiple realistic paths to achieve them. All pathways require significant improvements across the office's research areas, but 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 many opportunities for technology development. Figure 2, below, describes one potential pathway to $0.02/kWh by 2030.

[10] SETO. "Connect the Dots: Innovations in Residential Solar." https://www.energy.gov/eere/solar/connect-dots-innovations-residential-solar.

[11] DOE. *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.

[12] SETO. "Goals of the Solar Energy Technologies Office." https://www.energy.gov/eere/solar/goals-solar-energy-technologies-office. The 2030 PV LCOE targets are calculated based on average U.S. climate and without the Investment Tax Credit. For example, $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.

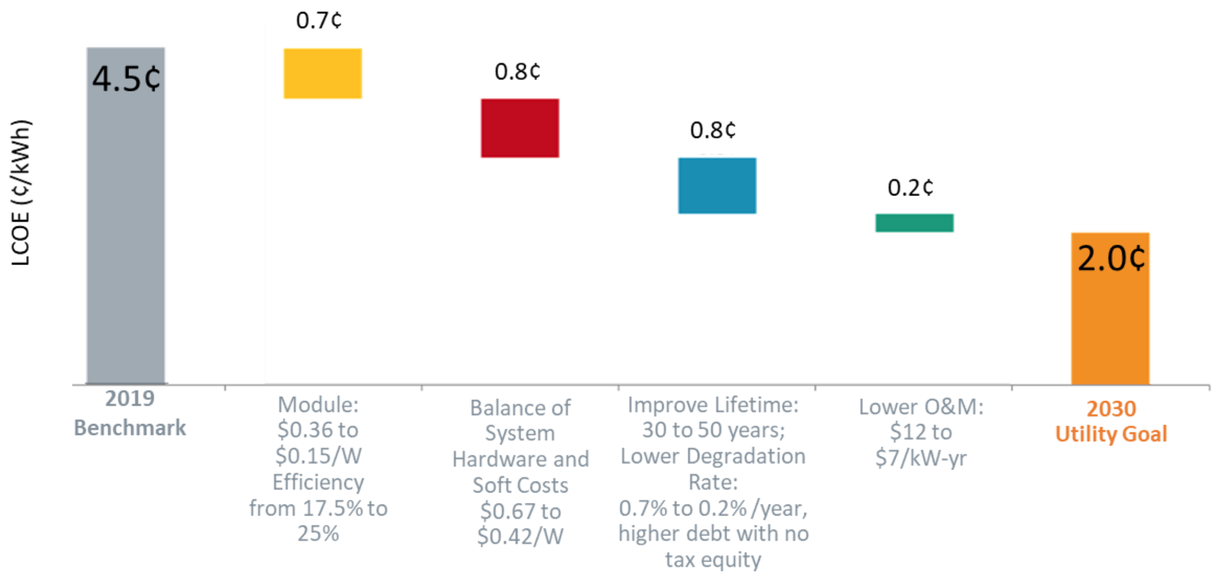

Figure 2. *One scenario for reaching the $0.02/kwh LCOE goal from the 2019 benchmark*[13]

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 plant efficiency. The Generation 3 Concentrating Solar Power Systems[14] (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 enable CSP systems to utilize advanced power cycles, based on supercritical carbon dioxide (sCO_2), that are much more efficient than existing steam-based cycles. The combination of Gen3 CSP systems with sCO_2 cycles is expected to lower the cost of a CSP system by approximately $0.03/kWh, which is 60% of the way toward SETO's 2030 cost goals of $0.05/kWh for baseload configurations.

Beyond CSP for electricity, the office works to make solar energy a cost-effective alternative to conventional fuels for industrial process heat. SETO pursues cost reductions and process integration improvements for a range of temperatures and industrial applications. Developing scalable, low-cost solutions for this variety of applications is a key challenge. SETO aims to make solar industrial process heat (SIPH)

[13] SETO. "2020 SETO Peer Review Presentations." https://www.energy.gov/eere/solar/downloads/2020-seto-peer-review-presentations.
[14] SETO. "Generation 3 Concentrating Solar Power Systems (Gen3 CSP)." https://www.energy.gov/eere/solar/generation-3-concentrating-solar-power-systems-gen3-csp.

cost-competitive with fossil fuels to provide a clean source of energy for difficult-to-electrify industrial processes. Candidate applications for SIPH include low-temperature processes, such as enhanced oil recovery, food processing, and water desalination, and high-temperature processes, such as calcination to produce cement, thermochemical water splitting for producing solar fuels, and ammonia synthesis for producing fertilizer.

SETO CSP Cost Goals

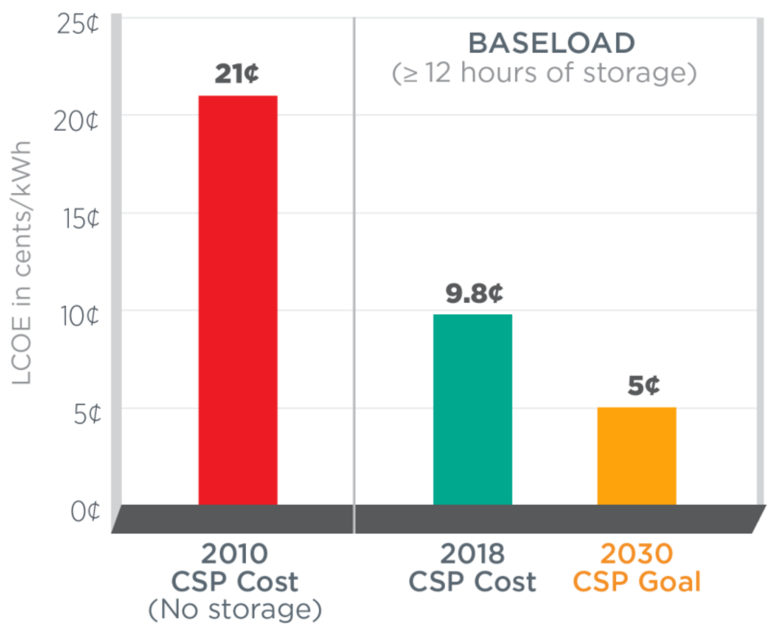

Figure 3. *2030 CSP LCOE cost targets for baseload power plants with 12 or more hours of storage*

This FOA also aims to broaden the solar R&D community. SETO is interested in proposals supported by diversity in experience and perspectives. Because SETO awardees often play a significant role in training future researchers and solar industry employees, the office requires applicants to this FOA to submit a plan proposing actions, within the scope of their projects, that can broaden the participation of well-qualified members of underrepresented groups on their teams. The office also encourages applications from members of groups traditionally underrepresented in engineering and science, and from early-career researchers who have never applied or been selected for a SETO project award.

iii. Diversity, Equity, and Inclusion

It is the policy of the Biden Administration that:

> [T]he Federal Government should pursue a comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality. Affirmatively advancing equity, civil rights, racial justice, and equal opportunity is the responsibility of the whole of our Government. Because advancing equity requires a systematic approach to embedding fairness in decision-making processes, executive departments and agencies (agencies) must recognize and work to redress inequities in their policies and programs that serve as barriers to equal opportunity.
>
> By advancing equity across the Federal Government, we can create opportunities for the improvement of communities that have been historically underserved, which benefits everyone.[15]

As part of this whole of government approach, this FOA seeks to encourage the participation of disadvantaged communities and underrepresented groups. As recognized in section 305 of the American Innovation and Competitiveness Act of 2017, Public Law 114-329:

> (1) [I]t is critical to our Nation's economic leadership and global competitiveness that the United States educate, train, and retain more scientists, engineers, and computer scientists; (2) there is currently a disconnect between the availability of and growing demand for STEM-skilled workers; (3) historically, underrepresented populations are the largest untapped STEM talent pools in the United States; and (4) given the shifting demographic landscape, the United States should encourage full participation of individuals from underrepresented populations in STEM fields.

Applicants are highly encouraged to include individuals from groups historically underrepresented[16] in STEM on their projects teams.[17] As part of the application,

[15] Executive Order 13985, "Advancing Racial Equity and Support for Underserved Communities Through the Federal Government" (Jan. 20, 2021).

[16] According to the National Science Foundation's 2019 report titled, "Women, Minorities and Persons with Disabilities in Science and Engineering", women, persons with disabilities, and underrepresented minority groups—blacks or African Americans, Hispanics or Latinos, and American Indians or Alaska Natives—are vastly underrepresented in the STEM (science, technology, engineering and math) fields that drive the energy sector. That is, their representation in STEM education and STEM employment is smaller than their representation in the

applicants are required to describe how diversity, equity, and inclusion objectives will be incorporated in the project. Specifically, applicants are required to submit a Diversity, Equity and Inclusion Plan (see Section IV.E.xiv of the FOA) that describes the actions the applicant will take to foster a welcoming and inclusive environment, support people from underrepresented groups in STEM, advance equity, and encourage the inclusion of individuals from these groups in the project; and the extent the project activities will be located in or benefit disadvantaged communities. The plan should include SMART milestones supported by metrics to measure the success of the proposed actions.

Further, Minority Serving Institutions, Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, Veteran Owned Businesses, or entities located in a disadvantaged community[18] that meet the eligibility requirements (see Section III) are encouraged to apply as the prime applicant or participate on an application as a proposed partner to the prime applicant. The Selection Official may consider the inclusion of these types of entities as part of the selection decision (see Section V.C.i of the FOA).

iv. Priority Research Areas

Achieving DOE's goals requires sustained, multifaceted innovation. Projects supported by this FOA[19] will focus on lowering the cost of PV and CSP technologies and creating new market opportunities for the industry, with the goal of enabling widespread deployment of solar to decarbonize the electricity grid and energy system. These projects will work to extend the lifetime of PV systems; make CSP applicable to new industries, like chemical production; advance the commercialization of new storage technologies; and address operational challenges in existing CSP plants.

U.S. population. https://ncses.nsf.gov/pubs/nsf19304/digest/about-this-report For example, in the U.S., Hispanics, African Americans and American Indians or Alaska Natives make up 24 percent of the overall workforce, yet only account for 9 percent of the country's science and engineering workforce. DOE seeks to reverse this troubling trend by working to inspire underrepresented Americans to pursue careers in energy and supporting their advancement into leadership positions. https://www.energy.gov/articles/introducing-minorities-energy-initiative

[17] As recognized in section 305 of the American Innovation and Competitiveness Act of 2017, Public Law 114-329:

[18] DOE defines "disadvantaged communities" to be areas that most suffer from a combination of economic, health, and environmental burdens, such as, poverty, high unemployment, air and water pollution, presence of hazardous wastes as well as high incidence of asthma and heart disease. Example include, but are not limited to: economically distressed communities identified by the Internal Revenue Service as Qualified Opportunity Zones; communities identified as disadvantaged communities by their respective States; communities identified on the Index of Deep Disadvantage referenced at https://news.umich.edu/new-index-ranks-americas-100-most-disadvantaged-communities/, and communities that otherwise meet the DOE definition of a disadvantaged community.

[19] SETO. "How to Apply for a Funding Opportunity Announcement (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding

One of the goals of publicly funded applied R&D is to mitigate the inherent risk of novel solutions. Key to achieving that goal is a systematic, domain-specific evaluation methodology, such as design of experiments, action research, or verification and validation testing. The testing itself should be preceded by well-designed test plans that examine the expected range of operation and generate statistical confidence in the results.

Engaging in R&D activities with the support of public funds comes with the responsibility to disseminate the outcomes to the nation's researchers, its industry stakeholders, and the general public. It is a goal of this FOA to encourage broad, open, and lasting access to research results, including important data sets and software code, that the projects generate. To broaden and amplify the impact of the R&D work, SETO supports commercialization efforts for the diffusion of the technologies, intellectual property, and expertise developed by the funded projects.

With this FOA, the office intends to fund ambitious, high-impact research in the following areas:

Topic Area 1: 50-Year Service Life PV Systems (PV-50)
This topic area will support research projects to address PV balance of systems challenges with the goal of increasing useful system life to 50 years while lowering the cost of energy. The aim is to improve PV system components such as inverters, connectors, cables, racks, and trackers through data analysis, sensor development for data gathering, characterization, component hardware improvements, more efficient O&M schedules, and increased durability. To achieve these goals, this topic solicits proposals for broad, multi-institution collaborations and targeted, smaller research efforts.

Topic Area 2: Scalable Outputs for Leveraging Advanced Research on Receivers & Reactors (SOLAR R&R)
This topic area will support research to advance novel solar receivers and reactors that will enable new applications for CSP systems. This includes advancing higher-temperature power towers for high-efficiency power cycles, solar reactors for thermochemical production of fuels and chemicals, or other solar process heat applications. This topic has a tiered application structure and uses risk-retirement objectives to scale up novel concepts and develop supporting information to enable commercial partnerships.

Topic Area 3: Pumped Thermal Energy Storage (PTES)
Projects in this topic area will advance PTES technologies that can use electricity to charge thermal energy storage, either as standalone systems or integrated with CSP plants. In particular, this topic area seeks to advance key PTES components, such as

compressors and heat exchangers; meet technoeconomic requirements for thermal energy storage; and prepare the innovations for manufacturing and commercialization.

Topic Area 4

This topic area seeks projects to advance technologies, training, and standards to reduce the costs of parabolic trough and power tower CSP plants. It is structured into two sections.

Topic Area 4a: Process Enhancement and Refinement For Operations, Reliability, and Maintenance (CSP PERFORM)

Projects in Topic Area 4a will focus on improving the reliability, operability, and productivity of existing CSP technologies. Projects will develop and evaluate solutions to reliability and performance issues that have been identified in existing CSP plants.

Topic Area 4b: Research in Equipment For Optimized and Reliable Machinery (CSP REFORM)

Projects in Topic Area 4b will focus on improving the design and operation of CSP plants by developing components and equipment for commercially relevant CSP systems that use conventional steam Rankine power cycles.

Topic Area 5: Small Innovative Projects in Solar (SIPS) – PV and CSP

Projects in this topic area will focus on innovative and novel ideas that are riskier than those based on established technologies. SIPS have a simplified application process, designed to encourage applications from engineering and science researchers in traditionally underrepresented groups, as well as early-career researchers who have never applied or been selected for a SETO award.

Topic Area 5a: SIPS PV

This topic area will support innovative and novel ideas in PV that can produce significant results within the first year of performance. Successful 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.

Topic Area 5b: SIPS CSP

This topic area will support small, focused projects investigating the applicability and robustness of novel ideas in CSP. Areas of interest include all aspects of CSP plants with thermal energy storage, as well as solar-thermal process heat innovations, solar-thermal fuel systems, and pumped thermal energy storage (PTES). Broadly, ideas may fall into two categories: early-stage efforts to elevate novel science and apply that to CSP; or innovative methods of closing a technical gap or limitation in an emerging technology, concept, or component.

v. Teaming Partner List

SETO strongly encourages teaming among multiple stakeholders across academia, industry, National Laboratories, and technical disciplines. Teams that include multiple partners are preferred over applications that include a single organization. Teams that include representation from diverse entities such as, but not limited to, minority-serving institutions (MSI), including historically Black colleges and universities (HBCU) and other minority institutions (OMI),[20] Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, Veteran Owned Businesses, or entities located in a disadvantaged communityare encouraged. To facilitate the formation of teams, SETO is providing a forum where interested parties can add themselves to the 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 at https://www.energy.gov/eere/solar/funding-opportunity-announcement-solar-energy-technologies-office-fiscal-year-2021 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: 50-Year Service Life PV Systems (PV-50)

This topic will support research projects to address PV balance of systems challenges with the goal of increasing useful system life to 50 years while lowering the cost of energy. The aim is to improve PV system components such as inverters, connectors, cables, racks, and trackers through data analysis, sensor development for data gathering,

[20] Minority Serving Institutions (MSIs), including HBCUs/OMIs as educational entities recognized by the Office of Civil Rights (OCR), U.S. Department of Education, and identified on the OCR's Department of Education U.S. accredited postsecondary minorities' institution list. See https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html.

characterization, component hardware improvements, more efficient O&M schedules, and increased durability.

SETO supports research in PV that increases the efficiency, improves the reliability and durability, and lowers the manufacturing cost of PV technologies to enable a carbon-free electric grid by the year 2035. To meet this goal, SETO is focused on quickly developing this research into practical solutions that 1) benefit U.S. supply chains, manufacturers, and infrastructure developers of PV technologies in terms of providing manufacturable, low-carbon-footprint materials and processes and 2) benefit consumers in terms of mitigating climate change while providing affordable electric energy by meeting the SETO LCOE goal of $0.02/kWh by 2030.

Past SETO programs have invested in advancing module component reliability (Physics of Reliability: Evaluating Design Insights for Component Technologies in Solar),[21] module durability (DuraMat Consortium),[22] and system reliability (SETO 2020 FOA, Topic 1). These research efforts have resulted in significant understanding of PV system reliability. To ensure that research advances are applied to challenges currently facing the solar industry, SETO funded collaborative projects between researchers and industry in the FY2019 funding program.

This topic aims to establish collaborations to accelerate PV system research efforts by bringing world-class U.S. research laboratories in academia, National Laboratories, and industry together to develop technologies that will enable PV systems with 50 years of service life. To ensure that project outcomes encompass a diversity of thought and experiences, research collaborations that involve institutions with different scientific resources, cultural backgrounds, and societal perspectives to develop holistic approaches are encouraged. These collaborative teams can apply for an initial three years of funding and a maximum award size of $3,750,000. Smaller, targeted projects with well-defined scope and focus will also be considered, for a maximum total project amount of $1,500,000.

There are many combinations of quantitative targets that would result in SETO's accelerated 2030 goal of $0.02/kWh LCOE for utility-scale PV systems. Achieving this aggressive goal will likely require improvements in the module, balance of system (BoS), and system lifetime. For example, added functionality to module designs that enable system operators to monitor degradation or failure of individual modules may lead to

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[21] Physics of Reliability: Evaluating Design Insights for Component Technologies in Solar (PREDICTS): https://www.energy.gov/eere/sunshot/physics-reliability-evaluating-design-insights-component-technologies-solar; PREDICTS 2: https://www.energy.gov/eere/sunshot/physics-reliability-evaluating-design-insights-component-technologies-solar-2-predicts.

[22] Durable Module Materials Consortium (DuraMat): https://www.energy.gov/eere/solar/durable-module-materials-consortium-duramat.

less costly O&M by efficient identification, prioritization, and preparation of module replacement. As another example, parts of the PV system racking could be designed with less expensive, more easily replaced components that would result in less downtime if they get damaged during a storm. By extending system lifetime, initial capital costs can be amortized over a longer time frame, thus reducing LCOE.

In the scenario in Figure 4, below, a significant LCOE reduction of 40% ($0.018/kWh) can be achieved by addressing system-level costs such as BoS hardware costs, increasing plant lifetime to 50 years, reducing the power-output degradation rate, and lowering O&M costs. This shows that system costs and performance have a large impact on LCOE.

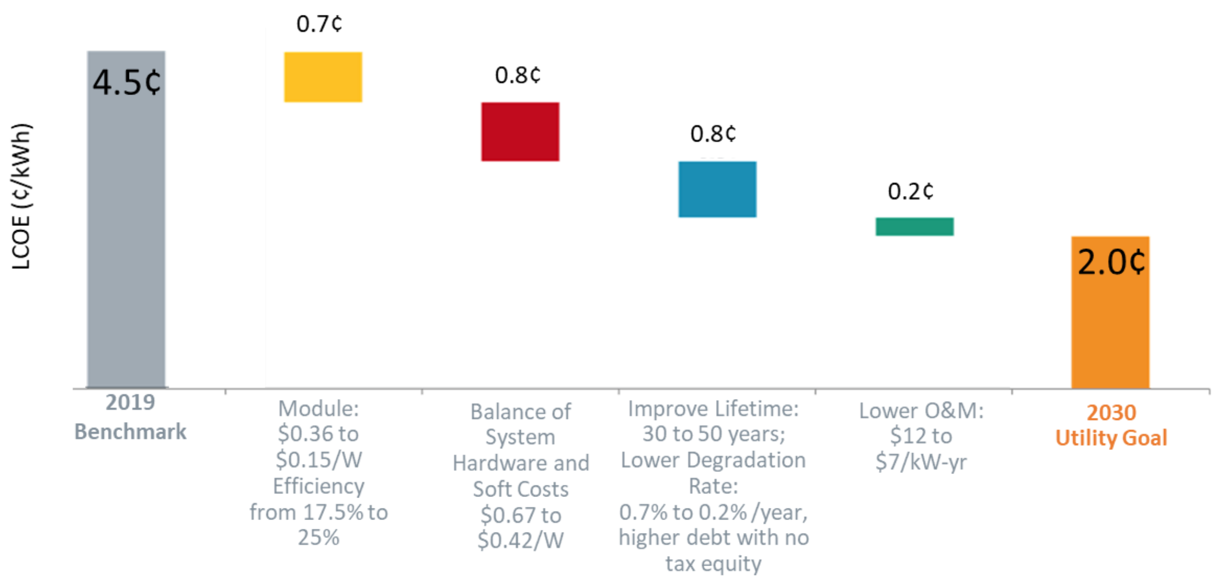

Figure 4. *One scenario for reaching the $0.02/kwh LCOE goal from the 2019 benchmark*[23]

Figure 5 shows a sensitivity analysis[24] of LCOE with respect to various PV system parameters showing the effect of:

- A 2% change in the weighted average cost of capital (WACC);
- Reducing capital expense (CapEx) by lowering installation costs with simplified and faster processes that enable increased installation speed;
- Increasing useful system life to 50 years by optimizing the design and materials selection of BoS component hardware for long life or periodic replacement;
- Reducing operational expense (OpEx) through higher reliability and more cost-efficient O&M; and

[23] 2020 SETO Peer Review Presentations. https://www.energy.gov/eere/solar/downloads/2020-seto-peer-review-presentations

[24] NREL, 2020. The baseline case is a plant in Kansas City with 5.1% WACC, $1.03/WDC CAPEX, 30 years useful system life, $17.50/kWyr OPEX, 1700 kWh/kW energy yield.

- Increasing the plant availability by reducing component downtime with rapid identification and replacement of underperforming components.

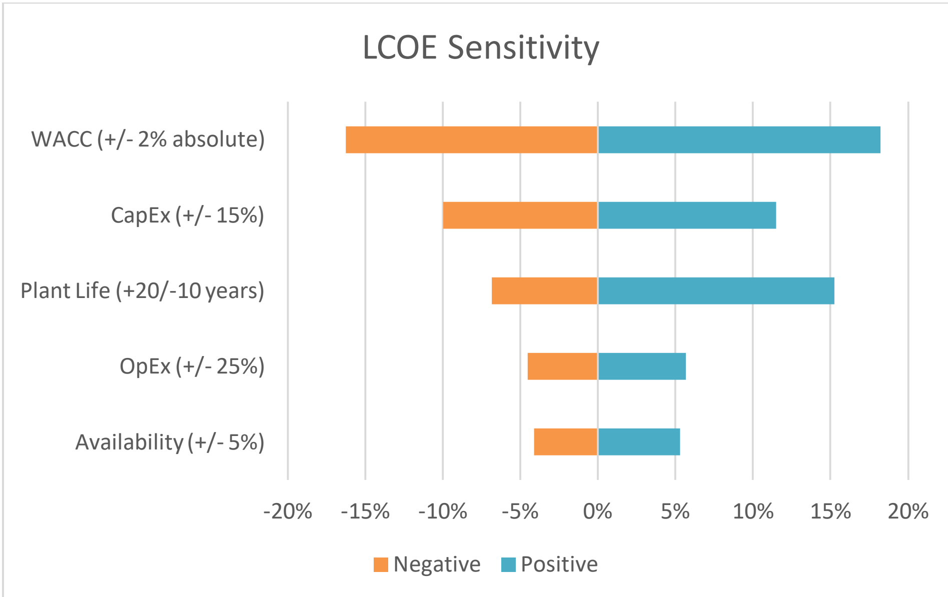

Figure 5. *Effect of various system parameters on LCOE*

As Figure 5, above, illustrates, LCOE can increase or decrease significantly when various factors change. One challenge in obtaining a 50-year PV system service life is that a decrease in LCOE in one factor may increase LCOE in another. For example, as seen in Figure 5, plant life may be improved 20%, representing a 7% LCOE reduction, but if improving the plant life requires using expensive materials, leading to a 15% increase in CapEx, the 7% LCOE improvement would be offset by a 12% increase in LCOE from the CapEx, resulting in an undesirable 5% net increase in LCOE (7% LCOE benefit from improved lifetime minus a 12% LCOE cost from higher CapEx). While this example is simplistic for illustrative purposes, an applicant's LCOE analysis should include sensitivity interactions among these factors, rather than treating them independently. Applicants to this topic area should illustrate how their proposed solutions may result in a net LCOE improvement of more than 20%, considering the factors shown in Figure 5.

Fortunately, several of these factors can be addressed together within a single subsystem improvement effort, resulting in additive LCOE improvement. The BoS improvement opportunities that are expected to provide the largest combined LCOE reductions are related to electrical interconnections, component modularity for optimized replacement schedules, and data management.

The direct current (DC) electrical system within a PV power plant comprises electrical connectors, combiner boxes, power cabling, data cabling and sensors, fuses, electrical grounding implements, and power electronics associated with the DC-side of central inverters or string inverters. This system is one of the greatest concerns for financing PV plants that last longer than 50 years, owing to the perceived risk of polymer material degradation, moisture-related corrosion, electrical leakage that may trip inverters, and mechanical fatigue of components due to motion or vibration. Further research regarding the reliability and durability of this system presents an opportunity to reduce assumed risk and improving predictive models. Improving the DC interconnection hardware that connects the solar panel junction box to other solar panels in a string, connects trackers to the DC power distribution cabling, or connects DC electrical branches to the home run cabling may also improve installation speed, quality, and safety, and increase energy production.

There may also be an opportunity to develop smart functionality within the DC electrical system that uses electrical signals and sensors to monitor electrical system health, track BoS component degradation, and locate faults. This data could be used to improve O&M efficiency, reduce downtime after damaging events, validate component reliability predictions, predict imminent failures, and inform best practices for engineering, procurement, and construction. Incorporating sensors may increase the cost of the system or, because of poor signal reliability, increase O&M costs, so applications in this topic area should carefully compare the cost risk and potential LCOE advantage of the proposed approach.

Another area of opportunity to extend useful system life is the development of modular components that allow system components to be easily replaced, upgraded, or retrofitted. Much like in traditional power plants, certain components will need to be replaced in a PV system due to normal wear and tear, manufacturing or installation defects, and damage from extreme weather events.

Ideally, good mechanical design choices could balance wear-out lifetime and component costs, as could a replacement schedule for components with a useful life of less than 50 years. Likewise, selecting quality materials and manufacturing processes could co-optimize the mean time between failures and the total cost of system ownership, including replacement expenses. These improvements can reduce the perceived risks to a system with a 50-year service life and result in greater system availability for energy generation, thus lowering risk premiums.

Understanding and improving the mechanical design of select system components to make them modular and, therefore, easily replaceable, can bring several opportunities to lower costs and boost energy production:

- Reduced CapEx costs through lower training costs, faster installation, and simple to install modular components;

- Reduced OpEx costs through reduced training and labor costs associated with system maintenance for random events, assuming a proactive replacement schedule;
- Improved system availability for energy production after weather or thermal events through faster recovery time, as a feature of easily replaceable modular components;
- Improved reliability and availability through simple and fast technological upgrades for greater energy generation.

Achieving the hardware objectives requires developing data acquisition and management strategies to monitor component parameters, troubleshooting root causes of degradation or failure, and gathering site data—particularly meteorological data. These data could improve learning rates for OpEx and BoS maintenance management, and directly lower LCOE over time by informing O&M personnel about when and how to replace components, identifying reliability weaknesses for component designers and engineering, procurement, and construction (EPC) firms, and quantifying the impact of manufacturing and installation quality for plant owners and independent engineers.

Below is a non-exhaustive list of priority areas, to illustrate some of the challenges that could be addressed by a successful application to this topic.

To lower LCOE to $0.02/kWh, SETO seeks applications that create hardware and software advancements to increase the reliability and bankability of "long-haul" PV systems with an operational life of 50 years or more. Optimizing systems for 50-year service life requires understanding which components should be designed for periodic replacement and which need better durability. This area of interest includes the mechanical and electrical structures and mechanisms of the PV plant on the DC side of the inverter, on-site metrology, and data subsystems. SETO is especially looking for technologies that address utility and commercial-industrial systems, because these systems are more likely to see value from a 50-year useful life.

The desired outcomes are cost-effective, system-wide solutions that address multiple BoS challenges. Some of the challenges specific to lowering LCOE that may be included as elements in the approach are:

- Data
  - Aggregating data from existing systems in diverse climatic regions and developing improved sensing capabilities and operational practices to improve their reliability and energy yield, especially under different weather conditions, including extreme events;

- Creating a cost-effective, reliable data acquisition infrastructure while using data standards, such as Orange Button,[25] to obtain and record sensor information over multiple decades to aid troubleshooting efforts for the purpose of improved O&M efficiency and systems engineering research;
- Methods to integrate reliability and failure models with field and manufacturer data for BoS components into the preliminary design and engineering of PV systems in different operating climates.

- Characterization and Sensors
  - Time-efficient imaging and other defect detection solutions, such as electroluminescence imaging or infrared thermography, to detect wafer cracking, hot spots, and other module-level latent or emerging defects for 100% inspection during installation or as part of periodic O&M activities;
  - Cost-effective in-line sensors in the electrical interconnection network to monitor voltage and electrical leakage currents that relate to specific degradation mechanisms, such as potential-induced degradation, structural corrosion, cable insulation degradation, faulty connections, and moisture-related electrical leakage;
  - Mechanical sensor networks to monitor mechanical loading and vibration on modules, trackers, racking, and other mechanical structures for the purpose of collecting data that can be used in predictive models and future mechanical design;
  - Automatic string-level disconnect in the event of ground faults or excessive electrical leakage instead of inverter tripping.
- Modular Components
  - Enabling rapid and robust system component replacement (including PV modules) for proactive, periodic maintenance schedules—solutions must address end of life, recyclability cost, and impact of used components;
  - Improving system robustness and resilience with regard to extreme weather; of particular interest are strategies and hardware to address hailstorm and hurricane damage mitigation.
- Durability of Mechanical Interfaces and Electrical Connections
  - Testing and validating mechanical connection and cable solutions that enable faster installation speed while simultaneously reducing human error and latent damage;
  - Improving the useful life of cabling, connectors, and other polymeric materials that may be subject to photo-oxidation, thermal degradation,

[25] Orange Button: https://orangebutton.io

moisture-related electrical leakage, corrosion, or mechanical failure within 50 years;
  - Developing mechanical-connection solutions that integrate electrical-connection functionality (for example, integrating wire management and electrical connectors into the module frame that mate with a connector embedded in the support structure);
  - Developing solutions to address mechanical fatigue in cable connections, such as trackers, and cabling that is subject to vibration, friction, variable wind, snow, and other mechanical loads;
  - Cabling and connection strategies that dramatically reduce the risk of thermal events and increase safety during installation and operation.

Successful applications to this topic will aim for a 50-year system service life and include the appropriate data elements listed above to identify the impact of BoS hardware advances. To increase project impact, teams that target inverter reliability should include the participation of and data contribution from at least three inverter manufacturers, owing to the diversity of inverters in the field. Applicants[26] must justify their proposed approach using data analysis, financial analysis, fielded deployment studies, published or original accelerated life studies, and fielded concept demonstrations. Applicants must also consider the path to commercial viability and justify that the proposed solution can provide a cost-competitive PV BoS technology. Solution demonstrations that use simulated weather or purposeful defects and fault events are encouraged when the probability of a natural event occurring within the project period is low.

Research collaborations are intended to run three to five years, with an expected maximum total project amount of $3,750,000 for the first three years. After three years of funding, SETO may choose to continue funding the most impactful and successful research collaborations for two more years. Smaller, targeted projects are intended to run for two to three years, with an expected maximum total project amount of $1,500,000. Collaborations that include HBCUs, tribal governments and institutions, or institutions that benefit underserved urban or rural communities are encouraged.

Highly innovative and novel ideas that are riskier than those based on established technologies or that address areas of PV research other than the BoS challenges covered above can apply for one year of funding under Topic 5a.

Areas Not of Interest

[26] https://www.energy.gov/eere/solar/how-to-apply-for-funding

- Theoretical modeling efforts not coupled with experimental approaches to increase system performance and decrease cost;
- Testing, characterization, and analysis research efforts not coupled with experimental approaches to increase system performance and decrease cost;
- Grid availability challenges, which are addressed in the FY 2021 Systems Integration and Hardware Incubator FOA;
- Solutions with no clear financial or supply chain path to implementation.

ii. Topic Area 2: SOLAR R&R: Scalable Outputs for Leveraging Advanced Research on Receivers & Reactors

This topic solicits projects to advance novel solar receivers and solar reactors that will enable new applications for CSP systems, including higher-temperature power towers for high-efficiency power cycles,[27] solar reactors for thermochemical production of fuels and chemicals,[28,29] or other solar process heat applications. This topic describes a tiered project structure and set of risk-retirement objectives to transition novel concepts to 1-5 megawatts thermal (MW_{th})-scale testing,[30] with sufficient supporting information to enable commercial adoption and operation.

Introduction

A fast and cost-effective decarbonization of the energy sector will require new technologies that can eliminate the need to burn fossil fuels for heat-driven processes that produce essential commodities, refined products, and other goods. The industrial sector emits over 20% of the nation's carbon dioxide emissions.[31] Industrial processes that rely on electricity will reduce emissions as the electric sector decarbonizes, but only 12% of industrial energy consumption is in the form of electricity.[32] CSP technologies can offer a way to eliminate the need for fossil fuels for these processes.

In a CSP plant, a solar collector field concentrates sunlight for conversion into thermal energy at the receiver, a specialized heat exchanger. The receiver component can also function as a solar reactor if an endothermic chemical reaction occurs in the same zone as the thermal exchange. Such a reactor can be used either for thermochemical energy storage—in a closed cycle—or production of solar fuels or other chemicals that are exported from the plant. Processes that can be realistically driven by concentrated solar-thermal energy are limited by the system design conditions (temperature, pressure, solar flux, etc.) and controllability (mass flow, chemical, property dispersion,

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[27] Mehos, Mark, Craig Turchi, Judith Vidal, Michael Wagner, Zhiwen Ma, Clifford Ho, William Kolb, Charles Andraka, and Alan Kruizenga. "Concentrating Solar Power Gen3 Demonstration Roadmap." No. NREL/TP-5500-67464. National Renewable Energy Lab (NREL), Golden, CO (United States), 2017.
[28] Yadav, D., & Banerjee, R. (2016). "A Review of Solar Thermochemical Processes." *Renewable and Sustainable Energy Reviews*, *54*, 497-532.
[29] Carrillo, A. J., González-Aguilar, J., Romero, M., & Coronado, J. M. (2019). "Solar Energy on Demand: A Review on High Temperature Thermochemical Heat Storage Systems and Materials." *Chemical Reviews*, *119* (7), 4777-4816.
[30] The National Solar Thermal Test Facility at Sandia National Laboratories will be available and potentially modified to provide one viable route to execute this test for selected technologies. https://energy.sandia.gov/programs/renewable-energy/csp/nsttf/
[31] EPA Greenhouse Gas Emissions: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#industry.
[32] Energy Flow Chart, Lawrence Livermore National Laboratory. https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2019.png.

etc.) of the mechanical and chemical environment at the receiver/reactor. Given that receivers and reactors are the primary components responsible for converting solar light into thermal or thermochemical energy, it is critical to develop cost-effective and efficient ones, as they are key technologies that can enable decarbonized electricity generation or industrial processes.

This topic solicits proposals[33] for novel solar receivers and solar reactors that will enable new applications for CSP systems, including higher-temperature power towers for high-efficiency power cycles, solar reactors for thermochemical production of fuels and chemicals, or other solar process heat applications. Applicants may consider:

- **Direct solar reactors**, where concentrated sunlight drives a chemical reaction without an intervening heat transfer medium (HTM);
- **Indirect solar reactors**, where the solar energy is used to power a reactor that is separated from the receiver but connected via a CSP-relevant HTM; or
- **Solar receivers**, where concentrated sunlight provides energy at the appropriate conditions, particularly at temperatures to enable thermal energy storage and dispatchable electricity production.

All innovations must justify the broad applicability and impact of the application they support.

[33] SETO. "How to Apply for a Funding Opportunity Announcement (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding

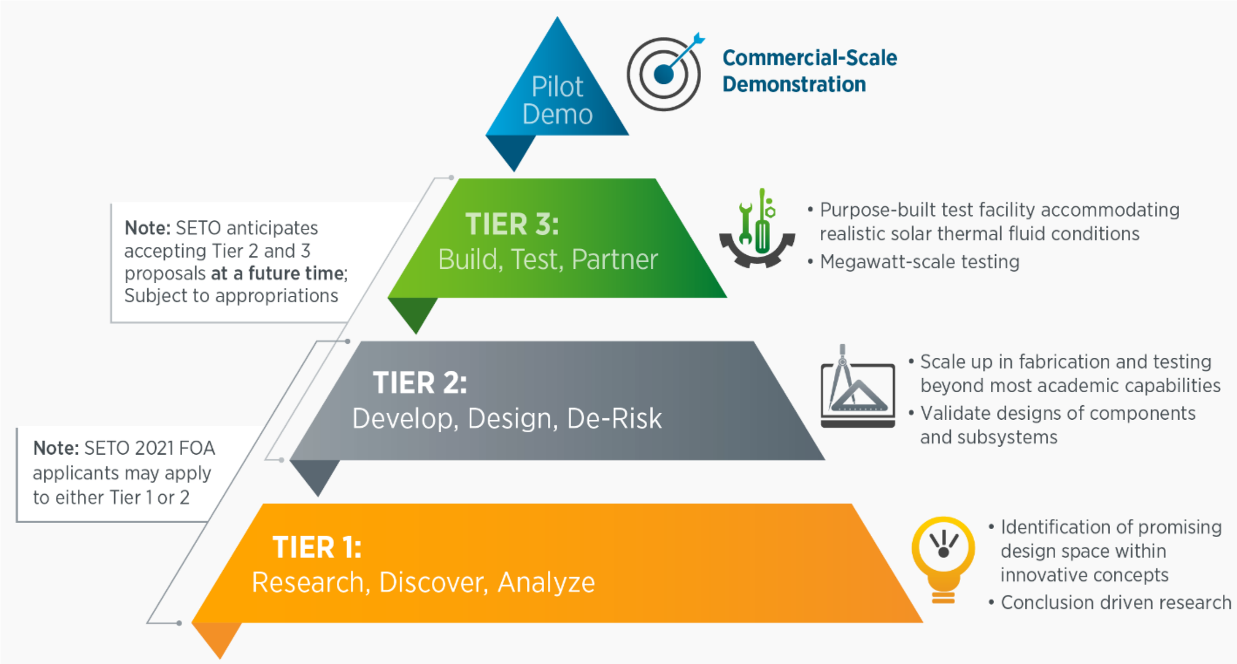

Figure 6. *SOLAR R&R Tier Structure. Funding for Tier 3 and a pilot demo are pending appropriations.*

Thermal systems are inherently challenging to de-risk and scale up owing to the typical non-linear correlation between device size and efficiency. Commercial CSP power towers use solar receivers at a scale of approximately 500 MW_{th} while laboratory prototypes are typically built at 1-10 kW. Many seemingly eloquent solutions at one scale are not transferrable to commercial sizes. The SOLAR Receivers and Reactors topic area is structured to simultaneously address the risks of scale and generate broad foundational knowledge to realize the value that comes from large-scale testing. Topic Area 2 will fund projects in Tier 1: “Research, Discover, and Analyze” and Tier 2: “Develop, Design, and De-Risk.” These tiers define the key outputs at each stage of the development of a novel receiver or reactor design required to gain confidence in the next R&D steps. The ultimate goal of this topic is to bring technology to the point of being ready to enter Tier 3: “Build, Test, and Partner.” Tier 3 projects will not be funded under this FOA, but SETO anticipates issuing another FOA to fund Tier 3 in the future.

Projects funded under this topic will be required to generate appropriate foundational knowledge for their technology readiness level (TRL), demonstrated risk reduction, and forward-looking scalable designs. The framework of this topic creates a path to achieving a pinnacle 1-5 MW_{th} testing showcase, as well as developing a detailed understanding of material and system properties, cost, manufacturability, operability, and other technical features to fully consider the benefits of the innovative system. These three SOLAR R&R tiers, described in detail below, will be funded independent of each other. Applicants may apply to Tier 1 or Tier 2 at this time, as dictated by the maturity of the proposed technology. Tier 3 concepts are not solicited at this time but are anticipated for future solicitation, pending availability of future appropriations.

Tier 1 is the "Research, Discover, and Analyze" tier. Projects in this tier will broadly determine the feasibility of highly novel ideas and begin to make bankable conclusions as appropriate for early TRL endeavors. Tier 2 is the "Develop, Design, and De-risk" tier. Projects in this tier will use new learnings to make credible arguments for the optimal design and operation of the proposed concept while addressing its highest-risk challenges.

Tier 3 is the "Build, Test, and Partner" tier and is not eligible for funding in this solicitation. Projects in this tier will be expected to execute testing of the novel concept at a scale adequate to discover and evaluate its potential shortcomings *in situ*. Projects that successfully complete this tier will have proven the viability of the technology adequate for adoption by commercial partners.

Appropriate activities for each tier are described in detail below. All applicants should strive to advance the technology systematically, reducing risks associated with all three tiers, and have a clear end goal of developing the technology for commercial demonstration. Proposals should describe the critical path of technology development through this endpoint, including capabilities needed for Tier 3 testing at 1 MW_{th} or higher capacity. Tier 1 and 2 applicants should consider potential appropriate testing sites for Tier 3 activities. DOE will work with awarded project teams to identify promising sites and integrate planning for potential Tier 3 activities. Tier 3 capstone testing may be suitable to take place at Sandia National Laboratories' (SNL) National Solar Thermal Test Facility (NSTTF). This is a unique, controlled-access research facility capable of delivering 5 MW_{th} solar flux onto a receiver. Applicants to Tier 2 do not need to team with SNL in advance or develop a budget to fund SNL for capstone testing. Applicants may team with SNL or other DOE National Laboratories on other tasks, which should be described in the application and budgeted for. Tier 2 applicants electing to plan for capstone tests at a site other than NSTTF must fully justify the appropriateness of that site in the application.

Research Background

This section reviews critical technical knowledge developed at SETO and elsewhere in the areas of solar receivers, relevant heat transfer media (HTM), high-temperature materials, solar reactors, and relevant chemical reactions.

Solar Receiver Research Background

To achieve SETO's 2030 cost target of $0.05/kWh for electricity production from baseload CSP plants with at least 12 hours of thermal energy storage (TES), recent R&D efforts have primarily focused on increasing the operating temperature and stability of heat transfer media and components, including receivers. This effort is primarily realized through the Gen3 CSP funding program,[34] which aims to develop a fully integrated thermal transport system, including a receiver and TES, able to deliver heat to an advanced power cycle based on sCO_2 at approximately 720°C.

Before the Gen3 CSP program launched, several promising novel receiver concepts were developed and tested at various scales, many of which are summarized in Table 1. But many of these concepts are not mature enough to be part of the integrated test facility being developed by the three project teams competing for DOE's selection of a single Gen3 pathway this spring. Nevertheless, a robust pipeline of innovation will ensure that system integration efforts, like Gen3, will have a diversified supply of concepts as cost and performance understanding improve. Applicants to this topic should have a demonstrated knowledge of relevant system concepts and previous R&D efforts to justify how their proposed receiver or reactor concepts will reduce cost or performance risk.

Table 1. *Advanced receiver concepts supported by SETO (continued on next page)*

Concept	Initial Innovation	Initial Risk	Accomplish-ment	Remaining Risk	Ref

[34] 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.

Micro channel nickel alloy receivers	Advanced manufacturing to enable small features in nickel alloys, enabling increased performance enabling high solar flux	Pressure drop; scaling; flow maldistribution; bonding	Completed designs with 25 kW performance testing	Scalable manufacturing; unit-to-unit integration; reliability of interfaces; combined creep/fatigue	[35] [36] [37] [38] [39] [40] [14]
Particle receivers	Open receiver and closed receiver forms overcoming poor optical-to-particle energy transfer	Operability; particle stability; low heat transfer coefficient	1 MW on-sun performance testing; material testing	Annualized performance, validated modeling, system control; creep failure for indirect concepts	[41] [42] [43]

[35] Sullivan, Shaun D., Kesseli, James, Nash, James, Farias, Jason, Kesseli, Devon, and Caruso, William. *High-Efficiency Low-Cost Solar Receiver for Use Ina a Supercritical CO2 Recompression Cycle*. United States: N. p., 2016. Web. doi:10.2172/1333813.

[36] Drost, Kevin. *High Flux Microchannel Receiver Development with Adaptive Flow Control*. United States: N. p., 2015. Web. doi:10.2172/1347906.

[37] Zada, Kyle R., Hyder, Matthew B., Kevin Drost, M., and Fronk, Brian M. *Numbering-Up of Microscale Devices for Megawatt-Scale Supercritical Carbon Dioxide Concentrating Solar Power Receivers*. United States: N. p., 2016. Web. doi:10.1115/1.4034516

[38] Hyder, Matthew B., and Fronk, Brian M. *Simulation of thermal hydraulic performance of multiple parallel micropin arrays for concentrating solar thermal applications with supercritical carbon dioxide*. United States: N. p., 2019. Web. doi:10.1016/j.solener.2018.02.035.

[39] Karki, Saroj, Haapala, Karl R., and Fronk, Brian M. *Technical and economic feasibility of solar flat-plate collector thermal energy systems for small and medium manufacturers*. United Kingdom: N. p., 2019. Web. doi:10.1016/j.apenergy.2019.113649.

[40] Sullivan, Shaun D., et al. "Mechanical Design and Validation Testing for a High-Performance Supercritical Carbon Dioxide Heat Exchanger." *Turbo Expo: Power for Land, Sea, and Air*. Vol. 50961. American Society of Mechanical Engineers, 2017.

[41] Ho, Clifford K. *High Temperature Falling Particle Receiver (2012 - 2016) - Final DOE Report*. United States: N. p., 2016. Web. doi:10.2172/1431441.

[42] Ma, Zhiwen, and Sakadjian, Bartev. *Near-Blackbody Enclosed Particle-Receiver Development*. United States: N. p., 2015. Web. doi:10.2172/1361458.

[43] Ho, Clifford K., Peacock, Greg, Mills, Brantley, Christian, Joshua Mark, Albrecht, Kevin, Yellowhair, Julius, and Ray, Daniel A. *Particle Mass Flow Control for High-Temperature Concentrating Solar Receivers.* United States: N. p., 2018. Web. doi:10.2172/1471496.

Silicon carbide (SiC) receiver for high efficiency and corrosion resistance	Monolithic SiC tubes, high thermal conductivity, chemical resiliency; SiC fibers for improved mechanical properties	Mechanical integrity, joining; headering, cost	Receiver efficiency modeling; materials testing	Mechanical integrity, joining/headering, material and manufacturing costs	[44] [45]
High-pressure sCO_2 cavity receiver	Use light trapping to overcome high emissive losses at >650°C	High-temperature materials, efficiency, cost	Optical testing, detailed design optimization	Pressure losses, material creep/fatigue	[46]
Vacuum-less trough receiver	Cavity-type linear receiver that requires no vacuum; uses adequate thermal insulation to maintain efficiency	Thermal efficiency, solar selective coating stability, efficient manufacture	Receiver efficiency modeling; field validation	Extended field operation, numbering up to an entire trough field	[47] [48]
Heat pipe	Passive flow wicking for low risk, low parasitic thermal transport	Manufacturability, performance limits	Isolated heat pipes manufactured and coupled	Integrated testing; operability	[49] [50]

In addition to receiver design, SETO has funded enabling R&D applicable to many receiver concepts, including advanced optical absorption coatings, improvements in manufacturing of nickel superalloy-based components, design tools for high-temperature receiver tubes, components for mass transport of heat transfer media, and advances in receiver metrology. SETO encourages applicants to leverage recent innovations to maximize the potential of their concept. [51] [52] [53] [54] [55] [56] [57]

[44] Walker, Matthew, Armijo, Kenneth Miguel, Yellowhair, Julius, Ho, Clifford K., Bohinsky, Amy, Halfinger, Jeff, and Feinroth, Herb. *High Temperature Silicon Carbide Receiver Tubes for Concentrating Solar Power.* United States: N. p., 2019. Web. doi:10.2172/1493845.

[45] Wait, David. *Development of 800°C Integrated Flow Channel Ceramic Receiver*. United States: N. p., 2018. Web. doi:10.2172/1460529.

[46] Wagner, Michael. *Direct s-CO2 Receiver Development*. United States: N. p., 2017. Web. doi:10.2172/1505150.

[47] Stettenheim, Joel, McBride, Troy, Brambles, Oliver, and Johnson, Leif. *Design and Field Testing of Manufacturable Advanced Low-Cost Receiver for Parabolic Trough Solar Power*. United States: N. p., 2019. Web. doi:10.2172/1508360.

[48] Stettenheim, Joel. *Second Generation Novel High Temperature Commercial Receiver & Low Cost High Performance Mirror Collector for Parabolic Solar Trough*. United States: N. p., 2016. Web. doi:10.2172/1332248.

[49] High Temperature Heat Pipe Receiver for Parabolic Trough Collectors. 2018. Steve Obrey. https://www.energy.gov/sites/prod/files/2016/08/f33/Collectors%20AM%2002-Obrey_Heat%20Pipe%20Linear%20Receiver.pdf.

[50] High Temperature Thermal Array for Next Genera7on Solar Thermal Power Production. https://www.energy.gov/sites/prod/files/2016/08/f33/08-CSP_SunShot%20Summit_LANL_Obrey.pdf.

[51] Jin, Sungho. *Low Cost High Performance Nanostructured Spectrally Selective Coating*. United States: N. p., 2017. Web. doi:10.2172/1350999.

Materials Considerations for Receivers or Reactors

For CSP receiver and reactor design, the combination of incident solar flux and heat transfer media outlet design temperature imposes stringent limits on material selection and design methods, especially for confined receiver geometries. New materials with properties that can accommodate long hold-time with low cycle fatigue and a sufficient overall component lifetime need to be evaluated. Ceramics, metals, and materials that can mimic both ceramic and metallic behaviors can all be considered, but design methodologies for each are significantly different.

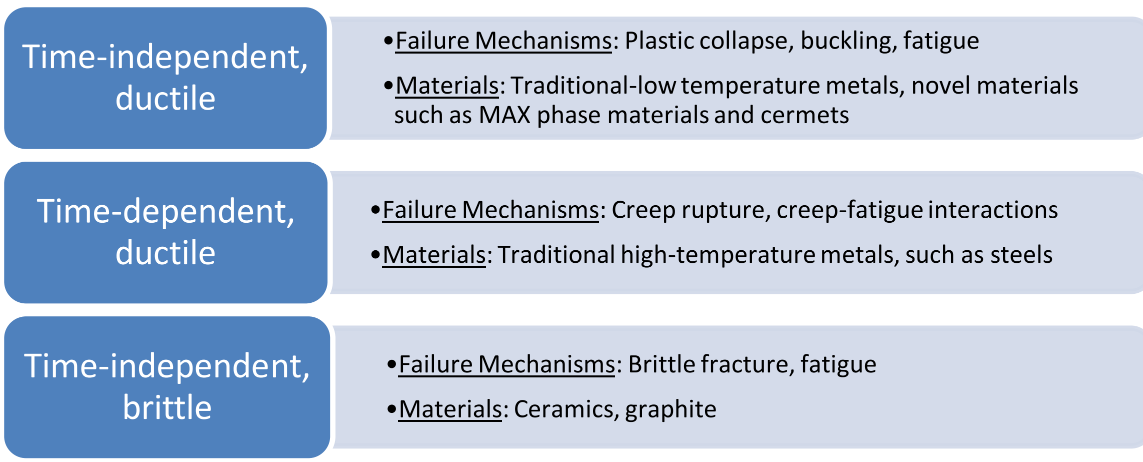

Figure 7. *Material classification by failure mechanisms*

Broadly, materials can be divided into three groups by failure mechanisms, as depicted above in Figure 7. For ductile materials where time-dependent strain occurs under load at elevated temperature, creep design methodologies are well established; recently,

[52] Ambrosini, Andrea. *High-Temperature Solar Selective Coating Development for Power Tower Receivers (Final Report)*. United States: N. p., 2016. Web. doi:10.2172/1505228.
[53] Elam, Jeffrey W. *Refractory Solar Selective Coatings*. United States: N. p., 2018. Web. doi:10.2172/1577428.
[54] Ho, Clifford K., and Pacheco, James E. *Levelized Cost of Coating (LCOC) for selective absorber materials*. United States: N. p., 2014. Web. doi:10.1016/j.solener.2014.05.017.
[55] Wang, Xiaoxin, Yu, Xiaobai, Fu, Sidan, Lee, Eldred, Kekalo, Katerina, and Liu, Jifeng. *Design and optimization of nanoparticle-pigmented solar selective absorber coatings for high-temperature concentrating solar thermal systems*. United States: N. p., 2018. Web. doi:10.1063/1.5009252.
[56] Sienicki, James J., Lv, Qiuping, and Moisseytsev, Anton. *High Efficiency Heat Exchanger for High Temperature and High Pressure Applications*. United States: N. p., 2017. Web. doi:10.2172/1404925.
[57] Ho, Clifford K., and Pattyn, Christian A. *Investigating Environmental Impacts of Particle Emissions from a High-Temperature Falling Particle Receiver (paper).* United States: N. p., 2019. Web.

creep-fatigue interactions for receiver design have been examined using data collected on high-nickel alloys.[58]

For brittle materials, the following steps are usually performed: A linear elastic component finite element analysis is performed, and an appropriate scalar effective stress for each element is calculated, followed by the determination of the allowable Weibull stress given the material's Weibull distribution, the finite element size, and an acceptable probability of failure. Completion of this analysis requires careful data collection (from literature and/or testing) and the determination of an acceptable probability of failure. Required data may include elastic constants, diffusivity, coefficient of thermal expansion, and material effective stresses.

The materials research community has not agreed upon an acceptable high-temperature design methodology for ductile, time-independent materials, but a robust data collection approach to inform ductile and brittle design lifetime is needed.

Last, composites such as ceramic-fiber, ceramic-ceramic fiber, and other components are potentially of interest. For these materials, collecting material property data and developing a lifetime model that is not specific to a single entity's manufacturing tools remains a challenge.

One method of receiver lifetime design uses fatigue-based damage approach, with direct accounting for the effects of thermo-mechanical fatigue and hold times at elevated temperatures in SAND93-0754.[59] The starting point of this approach is the isothermal low cycle fatigue dataset used to develop fatigue design curves for ASME Boiler and Pressure Vessel Code Case N-47.[60] Since the original data were not available for materials of interest (316 Stainless Steel and Alloy 800H), SAND93-0754 removed the safety factors of 2 on Δε (total strain range) and 20 on Nf (cycles-to-failure at the strain range of service) from the N-47 design curves. Safety factors of 1.5 on total strain range and 4.5 on cycles-to-failure at the strain range of service were recommended.

To extend the analyses to higher temperatures, Argonne National Laboratory (ANL) has developed a design guide for receivers.[61] The design criteria apply to components in CSP

[58] Barua, McMurtrey, Rupp, and Messner. "Design Guidance for High Temperature Concentrating Solar Power Components." ANL -20/03 158044, retrieved July 30, 2020, from https://publications.anl.gov/anlpubs/2020/01/158044.pdf.
[59] Wendell B. Jones, John J. Stephens. "Solar Receiver design, Treatment of Creep-Fatigue Interaction." SAND93-0754. *Applied Technology.* April 1994.
[60] ASME Boiler and Pressure Vessel Code Case N-47-29, Section III (Nuclear Power) of ASME Boiler and Pressure Vessel Code. December 1990.
[61] Bipul Barua, et. al. "Design Guidance for High Temperature Concentrating Solar Power Components." ANL-20/03; January 2020.

facilities at temperatures above 370°C for ferritic and ferritic-martensitic steels and 425°C for austenitic stainless steels and nickel-based alloys where creep-fatigue damage in cyclic service or stress relaxation damage caused by reoccurring application of secondary load is a significant design consideration. The design criteria were developed for structures undergoing daily cycling. Three options were provided: Design by Elastic Analysis using ASME Section III, Division 5; Design by Elastic Analysis using ASME Section III, Division 5 with Reduced Margin and Simplified Creep-Fatigue evaluation; and Design by Simple Inelastic Analysis. In addition, the design guidelines for life prediction were incorporated into a fast computational tool for estimating the life of a tubular metal receiver. A full 3-D analysis version of the tool with Alloy 740H material data is available as open-source software at https://github.com/Argonne-National-Laboratory/srlife.

Heat Transfer Media Research Background

The choice of heat transfer media (HTM) is foundational for CSP receiver design, and it drives most of the materials and design considerations. The Gen3 CSP program identified several HTM that showed promise in meeting SETO's electricity cost goals. The program was then organized by the phase of matter for leading HTM—gas, liquid, or solid. Released in 2017, the Gen3 Roadmap study describes the best understanding of potential Gen3 technologies.[62] Since 2017, additional relevant research and analysis has entered the public domain.[63] [64] [65] [66] [67] A brief overview of some applicable Gen3 HTM is provided below:

Chloride salt blends: A mixture of magnesium chloride, sodium chloride, and potassium chloride ($MgCl_2$-NaCl-KCl) is a leading salt-based HTM candidate for Gen3. Zinc chloride ($ZnCl_2$) is also considered in candidate mixtures to enable lower freeze temperature, but

[62] Mehos, Mark, Craig Turchi, Judith Vidal, Michael Wagner, Zhiwen Ma, Clifford Ho, William Kolb, Charles Andraka, and Alan Kruizenga. *Concentrating solar power Gen3 demonstration roadmap*. No. NREL/TP-5500-67464. National Renewable Energy Lab, Golden, CO (United States), 2017.
[63] Zhao, Youyang, and Judith Vidal. "Potential scalability of a cost-effective purification method for MgCl2-Containing salts for next-generation concentrating solar power technologies." *Solar Energy Materials and Solar Cells* 215 (2020): 110663.
[64] Vidal, Judith C., and Noah Klammer. "Molten chloride technology pathway to meet the US DOE sunshot initiative with Gen3 CSP." *AIP Conference Proceedings*. Vol. 2126. No. 1. AIP Publishing LLC, 2019.
[65] Albrecht, Kevin J., Matthew L. Bauer, and Clifford K. Ho. "Parametric Analysis of Particle CSP System Performance and Cost to Intrinsic Particle Properties and Operating Conditions." *Energy Sustainability*. Vol. 59094. American Society of Mechanical Engineers, 2019.
[66] Ho, C. K., Kinahan, S., Ortega, J. D., Vorobieff, P., Mammoli, A., & Martins, V. (2019, July). Characterization of particle and heat losses from falling particle receivers. In *Energy Sustainability* (Vol. 59094, p. V001T03A001). American Society of Mechanical Engineers.
[67] SETO CSP Program Summit 2019: Gen3 Gas Phase System Development & Demonstration. https://www.energy.gov/sites/prod/files/2019/04/f61/CSP%20Summit2019%20BraytonEnergy%20Sullivan%20Gen3.pdf.

corrosion behavior of $ZnCl_2$ is not yet well understood. Major impediments to Gen3 paradigms using this HTM in the receiver include catastrophic corrosion in the presence of oxygen or moisture, low thermal conductivity limiting the maximum thermal flux on the leading nickel alloy receivers, and freeze risk. The Gen3 liquid-phase team has determined that a liquid sodium receiver is ultimately less risky than a chloride salt receiver *with technologies presently available*, however this salt remains the leading choice of the Gen3 team to transport energy up and down a tower and to act as the TES medium.

Supercritical fluids**:** sCO_2 has been considered as a HTM for the Gen3 gas phase system. Major impediments to Gen3 paradigms using this HTM in the receiver include high-pressure and low thermal conductivity limiting the maximum allowable flux on nickel alloy receivers; high parasitic losses in circulation greatly impacted by pressure drop in the receiver; creep and fatigue failure of the receiver; and a higher receiver outlet temperature needed for additional temperature drops in indirect TES systems (such as particle beds). Despite these challenges, sCO_2 is a promising "gaseous" HTM, owing to its controllable flow and material compatibility at high temperatures. Leading Gen3 system designs for sCO_2 include a tubular receiver made of alloy 740H delivering energy to a sand TES medium.

Liquid sodium**:** Sodium is a well-known HTM with excellent thermophysical properties. Major concerns include catastrophic flammability; the cost of accounting for safety and fires; flux limitations on nickel alloy receivers; and corrosion uncertainties. Research into sodium receiver concepts must prioritize unique innovations to alleviate safety risks and the cost of safe operation.

Lead-bismuth**:** The eutectic mixture of lead and bismuth, and other non-sodium liquid metals, have not been considered for Gen3 CSP owing to the lack of maturity for compatible piping or receiver materials above 650°C. If this obstacle were overcome, challenges include the need for indirect TES and the hydrostatic head introducing mechanical containment challenges in the riser and downcomer.

Particles: Sand-like particles may avoid many of the issues associated with fluid high-temperature systems owing to the ability to operate at ambient pressure and with limited corrosion or thermal stability risk. Gen3 receiver challenges include operability limitations; risk of particle degradation with time at temperature; scaling limitations, and general challenges in receiver efficiency and heat transfer.

Applicants should identify which medium or media the project will target for integration with their receiver and ultimate commercialization effort. It is conceivable that an early-stage concept may explore multiple candidate HTM. All applicants should carefully consider system integration challenges relevant to their concept, including oftenoverlooked components like headers, valves, freeze protection, safety equipment, and others.

Solar Reactor Research Background

In addition to the LCOE goal of \$0.05 per kWh_e for baseload[68] CSP electricity, SETO seeks to identify pathways for solar-thermal energy to become a cost-effective alternative to conventional fuels for industrial use. Thus, SETO is also targeting \$0.02 per kWh_{th} for delivered heat.[69] The heat market is more disparate than electricity markets. For many thermal applications, proposals may choose to justify a different LCOH goal. This heat may be delivered directly, by integrating solar collectors and TES with a thermal process, or by thermochemical synthesis of fuels or other chemical commodities that can be readily transported and used for a variety of applications to transfer embedded solar-thermal energy. Solar thermochemical fuel synthesis is particularly attractive because the production of energy-dense, easily transportable fuels allows for the decoupling of geographical and temporal limitations of solar energy availability. Thermochemical processes may also be attractive in a *closed cycle* for CSP electricity generation, as thermochemical reactions typically have a significantly higher gravimetric and volumetric energy density per unit of storage medium than conventional sensible heat storage in media like molten salts.

The potential value of solar thermochemical systems requires the added complexity of operating, in conjunction, both a solar-thermal facility and a chemical plant. The diurnal nature of solar is at odds with the 24-hour operations typically required to achieve profitability in a commodity chemical facility. The diurnal challenge is compounded on even shorter timescales by clouds and on longer time scales by seasons. Nonetheless, oversizing the solar input relative to the downstream processing capacity of the chemical facility creates an opportunity in which (a) reservoir(s) of solar-thermal heat may be stored to ensure continuous, reliable operations and/or (b) a transient inventory of thermally processed chemical may be built up, allowing for continuous downstream operations. In an extreme case, a very large inventory of processed chemical may be produced and stored cost-effectively to (a) enable seasonal thermal/thermochemical energy storage for electricity generation and/or (b) allow sale of the chemical produced in response to seasonal market demand, such as with ammonia-based fertilizers in the agricultural sector.

Besides economic and operational challenges, many technical challenges must be addressed to make solar thermochemical reactors commercially viable. These devices

[68] Baseload is defined as CSP plants with greater than 10 hours of storage able to operate at least 66% of the year.
[69] It is clear that process needs such as temperature, size, and location of a process will impact this target, so this target is suggestive, not definitive. It includes the cost of collectors, receiver, TES, and thermal transport system.

must address nearly all the challenges associated with a much simpler solar receiver while respecting the thermodynamics, chemical kinetics, pressures, temperatures, heat transfer, materials handling, separations, yields, and capacity factor needs of a chemical plant. Furthermore, solar-thermal plants must be augmented to chemical processing facilities cost-competitively.

Achieving cost competitiveness against conventional processes will require significant innovation and a targeted technoeconomic strategy. Applicants should clearly articulate this strategy, at least at a high level, for all tiers into which they apply. A non-exhaustive list of possible technoeconomic strategies include:

- **Process intensification** – An equipment and operations strategy wherein a single piece of equipment is used to perform multiple processes or operations. As opposed to conventionally engineered systems consisting of a linear sequence of unit steps, fewer pieces of equipment—and, typically, lower capital and operating costs—are targeted.
- **Vertical integration** – A single entity owns facilities carefully designed to interface and do two or more related, sequential processes. This approach differs from process intensification in that the entity feeds a raw material into the first process to produce a finished, marketable product that is then retained as an input to a second process, perhaps with additional inputs of material and energy, to produce a second marketable product of even higher value than the first.
- **Value-added products** – Production of marketable chemicals in a uniquely advantageous format for use in subsequent processes. In some cases, conventional sources of a raw material may be inferior, owing to the additional processing required to enable industrial utilization. For example, a solar thermochemical reactor may be capable of producing a metal powder from ore in a purity particle size distribution for direct use in an additive manufacturing process. Such a powder may be seen as being more valuable than an ingot of the same metal that would require further processing to convert it into usable powder.

Tables 2 and 3 below summarize the key attributes of several potentially interesting thermochemical cycles, for both closed-cycle storage of thermal energy for electricity production, and open-cycle production of fuels and chemical commodities. Table 3 is an overview of previous SETO-funded work and accomplishments in this area.

Table 2. *A few examples of the classes and types of thermochemical reactions relevant to CSP*[70,71,72]

Class	Type	Energy (MJ/kg)	Temperature (°C)	Pressure (Bar)	Challenges
On-site Thermochemical Storage Media	Metal hydrides	1.2-8.4	250-1000	10	Costs; reactivity; hydrogen (H_2) embrittlement; thermal conductivity/heat transfer
	Metal carbonates	1.6-1.8	850-1200	1	Storage of CO_2; low cyclic stability/loss of capacity; thermal conductivity/heat transfer
	Metal oxides stoichiometric or non-stoichiometric	0.2-1.1	500-1500	0.0001-1	Stoichiometric: Low cyclic stability/loss of capacity; low thermal conductivity/heat transfer Non-stoichiometric: Low capacity; low thermal conductivity/heat transfer; higher cost
Chemical Commodity or Product	Ammonia (NH_3)	3.9	350-650	100-300	Storage of H_2; generation of pure nitrogen (N_2); requires catalyst; moderate reaction enthalpy
	Hydroxides	1.3-1.4	350-600	1-5	Low discharge temperatures; slow discharge rates; low cyclic stability/loss of capacity
	Sulfur trioxide (SO_3)	1.2	500-1000	1-25	Requires catalyst; yields at equilibrium are low; formation of sulfate (SO_4^{2-}); sulfur embrittlement; oxygen separation
	Elemental sulfur	9	150-1200	1-30	Multistep cycle; low yields; requires catalyst, formation of sulfate (SO_4^{2-}); corrosion, sulfur embrittlement; requires sulfur combustor

[70] Carrillo, A. J., González-Aguilar, J., Romero, M., & Coronado, J. M. (2019). Solar energy on demand: A review on high temperature thermochemical heat storage systems and materials. *Chemical reviews*, *119*(7), 4777-4816.
[71] Safari, F., & Dincer, I. (2020). A review and comparative evaluation of thermochemical water splitting cycles for hydrogen production. *Energy Conversion and Management*, *205*, 112182.
[72] Muhich, C. L., Ehrhart, B. D., Al-Shankiti, I., Ward, B. J., Musgrave, C. B., & Weimer, A. W. (2016). A review and perspective of efficient hydrogen generation via solar thermal water splitting. *Wiley Interdisciplinary Reviews: Energy and Environment*, *5*(3), 261-287.

	Benzene hydrogenation	2.5	300	1-30	Storage of H_2; requires catalyst; side reactions; low cyclic stability/loss of capacity
Fuel	Metal oxides stoichiometric	0.2-1.1	500-1500	0.0001-1	Stoichiometric: Low cyclic stability/loss of capacity; low thermal conductivity/heat transfer
	Water splitting (H_2) (various approaches)	120-142	25-1800	1-30	Solids handling; cost of containment materials; corrosion; separations; low yields; multistep cycles; side reactions; slow kinetics
	Methane reforming	15.6	1000	100	Storage of H_2; storage of CO_2; requires catalyst; side reactions; low cyclic stability/loss of capacity

Table 3. *Prior SETO research in solar thermochemical systems*

Reactor/Reaction Concept	Initial Innovation	Initial Risk	Accomplishment	Remaining Risk	Critical Data
Sulfur/H_2SO_4 Looping; Sulfur Combustion	Silicon carbide honeycomb + catalyst cavity reactor for SO_3/SO_2; iodide-based catalyst for SO_2 disproportionation	Formation of sulfate; low SO_2 yield; low sulfur yield; separations	Thermodynamic equilibrium vs. materials containment trade-off; better SO_3 cracking catalyst	Thermal efficiency, corrosion, process intensification	Final Report
Chemically Reactive Working Fluids	Increased "heat capacity" by combined sensible energy and enthalpy of reaction	Identification of fluids and catalysts; side reactions; degradation of capacity	Prioritized list of fluids and possible catalysts	Endurance testing	
Microchannel Steam Methane Reforming	Steam methane reforming via microchannel dish-based receiver/reactor	Reactor manufacturability/survivability; thermal management; energy storage	Microchannel receiver/reactor built and tested on-sun	Energy storage	Final Report
Chemically Reactive Carbon Particles	Volumetric absorption into soot-like particle clouds which totally oxidize away	Quartz window and seal; reaction kinetics; particle generation; high temp materials	Evaluated particle generation and dispersion strategies; tested window seals	Optimizing volumetric absorption and reaction rates; quartz window	Publication

Metal Carbonates	Mayenite dopant to promote kinetics and preserve cyclic stability; or carbonates loaded on a mesh support; support prevents sintering/loss of capacity	Particle sintering, loss of capacity, heat transfer; pressure drop; CO_2 storage	Stable capacity even at 500 cycles; map equilibrium as function of parameters; direct contact reaction with sCO_2; CO_2 bladder storage	Heat transfer, pressure vessel costs; mesh-supported systems still sintered/lost capacity upon cycling	Final Report
High Temp/Low Temp Metal Hydride Beds	Shuttle H_2 between two metal hydride beds, exploit enthalpy of reaction; avoid storing hydrogen as gas	Identify a viable metal hydride for 700+°C; thermal conductivity; cost	New high-temp metal hydride; test data of heat transfer enhancement; capacity stable	Costs of metal hydride and heat transfer enhancement	Final Report
Thermochemical Storage with Anhydrous Ammonia	Increase operating temperature to 600° or 650°C; decompose ammonia to release stored energy; reform ammonia to complete the cycle	Identify catalyst for the increased temperature; cost-effective generation of pure N_2; cost-effective storage of NH_3 and H_2; reactor design and thermal management	Demonstrated steam heating to 650°C, energy recovery to steam at 5 kW_{th}; cost modeling of NH_3, H_2 storage in salt caverns and drilled shafts	Costs; novelty of storage strategy	Final Report Article 1 Article 2
Perovskite Solar Particle Receiver	Mixed ionic electronic conducting oxides, rapid kinetics, reduced sintering	Low total chemical capacity per gram (g) metal oxide; requires controlled atmosphere	Screened many compounds; established reduction kinetics and capacity; re-oxidation kinetics	Low capacity per g metal oxide, controlling receiver-reactor chemical environment	Slides Report Poster Article 1
Metal Sulfides	One of the highest volumetric energy densities, approaching that of methanol	Kinetics not well characterized; materials compatibility concerns; heat transfer; mass transfer	Established preliminary kinetics; evaluated preliminary reactor designs; prioritized metal sulfide by cost and performance	Materials containment; needs multiple cycle tests; mass transport of sulfur into metal; heat management	

Technical Requirements

Many specific concepts will have unique technical requirements owing to the viable technoeconomic solution space for the integrated concept, as well as specific high-risk areas of the technology. This section broadly describes targets that can integrate into cost-competitive solar-thermal concepts.

Solar Receiver Technical Requirements

At the most basic level, three metrics determine the impact of a receiver on the levelized cost of energy: cost ($/kW$_{th}$), efficiency, and lifetime. While a broad solution space exists between these metrics and other technoeconomic variables of the system, these targets can help focus applications. Applicants may apply with targets outside those described if the proposal can show a system pathway to achieving the critical technoeconomic target, such as baseload power generation at $0.05/kWh LCOE. Otherwise, applicants must indicate a viable pathway to achieving these requirements through the work funded under this topic.

Cost: $150/kW$_{th}$. This cost includes the receiver panel, tower, piping (riser, downcomer), interconnects, cold pump or equivalent, and auxiliary components (valves, sensors etc.). It is reasonable to consider the receiver panel and interconnects to be 50% of this cost target.

Efficiency: 90% optical-to-thermal efficiency. This target accounts for all thermal energy incident on the receiver target area compared with the amount of thermal energy that can be delivered to thermal energy storage. Optical properties of the receiver material must be accounted for, as must convection (including realistic wind speeds) and conduction losses, and heat that cannot be recuperated (or how to recuperate lost heat). Additionally, most systems will need appropriate pressure drop targets developed, as well as a second law of thermodynamics analysis to fully understand the impact of thermodynamic irreversibilities on the quality of energy delivery.

Lifetime: 30 Years. A 30-year plant lifetime is typical in the financial models that inform SETO's cost and performance targets. As in all thermal plants, replacement of parts can be a viable O&M strategy. If equipment replacement is proposed in submissions, the increased operational cost should be offset by reduced capital cost, efficiency improvements, or other attributes of the integrated system.

Solar Reactors Technical Requirements

Direct and indirect receiver-reactors are necessarily more complex than traditional solar receivers. While similar metrics to those used to evaluate receivers should be considered for thermochemical systems, there may be substantial uncertainty in achieving these. Nonetheless, the same general strategy applies: Maximize the receiver-reactor's capability (chemical gradients, reaction rates, separations, etc.) maximize efficiency (consider parasitic loads), maximize lifetime and reliability, etc.—while optimizing cost versus benefits.

Please include analysis for significant divergence from established solar receiver metrics and identify critical parameters. Applicants should include the values they plan to achieve for each of these parameters, the assumptions involved in achieving them, and an explicit description of how they will optimize interrelated groups of these parameters. The following is a non-exhaustive list of possible parameters for inter-optimization:

- Extent of thermodynamic equilibrium
- Temperature (minimum, maximum, gradients)
- Pressure (minimum, maximum, gradients)
- Concentrations (minimum, maximum, gradients)
- Applied potential (minimum, maximum, frequency of oscillation)
- Kinetics (rate, range of rates)
- Purity of product
- Mass flow
- Corrosion rates of receiver-reactor or containment vessel
- Receiver-reactor absorptivity and emissivity at targeted operating temperature (for direct receiver-reactors), as well as the assumed rate of change in these as a function of time

Optimization and trade-off analysis should indicate whether values will be modeled outcomes, measured outcomes, or projections built upon inputs from model and experiment. All assumptions must be explicitly stated. This topic seeks technology development plans that can credibly advance technologies beyond the laboratory.

Tiers and Stage-Gates

Tier 1. Research, Discover, Analyze (RD&A)
Up to 3 years, up to $3 million

Applicants to Tier 1 should seek to prove (or disprove) that a novel innovation has adequate merit and advantage to advance to extensive testing campaign and system development efforts in Tier 2. Critical tests, protocols, simulations and analyses to understand and develop quantitative descriptions of key performance variables should be designed and completed. Relevant prototypes at the 1-50 kW scale should be fabricated and studied in low fidelity testing environments at appropriate temperatures. Based on initial testing insights, a preliminary design of a 1-5 MW prototype, including an initial risk assessment, should be completed, with sufficient detail to inform future development needs. As the design and risk assessment are developed, they should iteratively influence Tier 1 activities in real time. A cost analysis framework should be developed with appropriate sophistication for subsequent performance/cost trade-off evaluations, to include uncertainties in these projections. Each of these objectives should have clearly defined success metrics and quality assurance methodologies (i.e., assessment tools).

En route to prototype testing, applicants should explain how they will adequately explore appropriate discovery space to either give confidence that leading candidates for critical aspects of the systems have been identified, or that no candidate exists and thereby disprove the technology viability for the application. Convincingly disproving a concept is considered a meritorious outcome. This often leads to collaborative redirection of effort to more impactful areas. Measurement campaigns of critical intrinsic variables and system operation variables must be adequate to inform a future optimized design. Moderate-to-aggressive mechanical and chemical accelerated lifetime studies should be completed as appropriate.

Applicants[73] to Tier 1 should explicitly plan to graduate their project, if successful, to Tier 2 and/or Tier 3 of this topic area. Subject to congressional appropriations and strategic directions, SETO intends to periodically release FOAs with this or a similar topic, to support the multi-scale development of CSP-relevant technologies. Successful Tier 1 projects would need to apply to a future solicitation to advance work to Tier 2.

Tier 2. Develop, Design, De-Risk (DD&D)
Up to 3 years, up to $5 million

Submissions to Tier 2 should build a case that demonstrates that the novel proposed concept is adequately understood to have a reasonable chance of commercial adoption with further development, testing, and demonstration. This will likely include high-fidelity lifetime testing and a sophisticated engineering analysis of the concept; detailed cost analysis of the commercial concept, including design for manufacture consideration; high-fidelity performance modeling; integrated material testing campaigns; an initial design of a 1-5 MW pilot ready to be fabricated; and a nominal design of a commercial-scale concept. In this tier, the team should have significant engagement with industry stakeholders to inform both application value and credibility of system cost and feasibility. Uncertainties around cost of components, operational strategies, and system integration should be substantially less than in Tier 1. These reductions in uncertainties should come from obtaining multiple quotes for each component where possible, achieving multiple measurements of properties and performance in moderate fidelity environments, and understanding the needs of multiple potential commercial adopters. Furthermore, significant engagement with a candidate Tier 3 test facility should begin,

[73] https://www.energy.gov/eere/solar/how-to-apply-for-funding

to ensure feasibility of successful testing of a 1-5 MW pilot. Capstone testing in Tier 2 should include a prototype on the 100-500 kW scale in a directionally heated environment, to simulate solar input, which can stimulate short-term failure mechanisms and validate models used to design the MW-scale system.

A detailed plan for Tier 3 should be developed in Tier 2. This includes build-out plans at a test facility, initial fabrication and procurement plans, a prospective testing campaign, and a carefully considered risk registry of the system. Formalisms such as failure modes and effects analysis should be employed to minimize the risk of failure at the MW scale. By the end of Tier 2, the team should be able to estimate the budget needed to execute a Tier 3 effort with a high degree of certainty. Efforts in Tier 2 should be advanced enough that a complete engineering design package can be finalized early in Tier 3, if awarded. Depending on the required build-out, many concepts will require incorporating an engineering, procurement, and construction (EPC) firm into the team during Tier 2.

Since the Tier 3 actions are Build, Test, and Partner and will likely represent a large investment of federal funds and cost share, Tier 2 projects should develop a high degree of confidence in the estimated budget for a Tier 3 effort, a mastery of the technical challenges, and a proactive plan to respond to unanticipated occurrences using the validated functional relationship established through Tier 1 and Tier 2.

Applicants[74] proposing the advancement of concepts that have overcome significant early TRL risks but require further research to resolve high-risk aspects and ultimately justify novel testing at the 1 MW scale are not required to request the full three years available for a Tier 2 project. However, they should still plan to demonstrate that they are able to retire Tier 2 risks described above and develop a high-confidence project plan and budget for entering Tier 3. Technologies that have retired some but not all Tier 1 risks should apply to Tier 2 only if remaining Tier 1 and Tier 2 risks can be retired in three year period.

Tier 3. Build, Test, Partner (BT&P)
Time frame and budget allowances to be determined, pending future appropriations.

SETO is not currently accepting applications to Tier 3. However, the following summary is included to inform Tier 1 and 2 applicants of the eventual goals of Tier 1 and 2 projects.

[74] SETO. "How to Apply for a Funding Opportunity (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding.

Based on the outcomes of Tiers 1 and 2, Tier 3 will encompass procurement, build-out, testing, and validation activities at an identified test facility. Research team(s) will finalize a proposed testing campaign that maximizes understanding of the component and minimizes risk transitioning this idea to an integrated pilot plant. Tier 3 projects should be designed to demonstrate sufficient validation to enable further investment and development by the private sector. Beyond specified testing campaigns to validate performance or endurance, projects in this tier should include extended on-sun testing, at a rate no less than 1 MW_{th}, to prove the quantity and quality of the product of interest (thermal energy, a specified chemical, etc.) as a function of solar irradiance. Total receiver or reactor testing time is anticipated to be 100-250 hours and should include long-term material testing, failure rate studies, exploration of system transients, and high-risk integration tests, along with development of detailed system designs and commercialization strategies.

Technical Merit

This solicitation seeks applicants[75] who will champion overcoming significant risks and barriers to commercial adoption of their proposed solutions. Submissions can demonstrate merit by appropriately identifying activities needed to achieve successful commercial partnerships. Formalisms such as Ishikawa diagrams (fishbone diagrams) are strongly encouraged to demonstrate the applicant's holistic knowledge of cause and effect relationships in the project and the interrelated nature of the challenges.[76]

Table 4. Risk Retirement Activities by Tier. *This table contains suggestions of risks to consider. They are not applicable to all concepts, and this table is not exhaustive. These items are only briefly described, so it is critical that applicants pursue their bankability and identify risks and knowledge needs beyond this list as appropriate to the technology. Methodologies should be described to help guarantee the fidelity of each risk item.*

	RD&A (Tier 1)	DD&D (Tier 2)	BT&P (Tier 3)
Thermal Efficiency	Measure isolated thermal, optical, hydraulic, reaction properties; determine properties to stated confidence interval; model integrated component	Measure subscale component performance; develop and validate modeling of system transients; prove performance parameters as a function of operating conditions	Prove modeling in advance TRL scenario; minimize performance uncertainty
Mechanical Survivability	Measure new and rapidly aged properties of critical	Develop pathway to code case quality data; predict	Finalize pathway to relevant code case; do post-testing

75 SETO. "How to Apply for a Funding Opportunity (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding.

76 Ishikawa, Kaoru (1968). *Guide to Quality Control*. Tokyo: JUSE.

	subcomponents and interconnects; incorporate lifetime understanding into design decisions	lifetime to high fidelity; long-term, redundant subcomponent testing; integrated prototype testing	analysis of MW-scale prototype; supporting measurements
Chemical Survivability	Screening and initial lifetime testing; theoretical interactions developed and tested	Long-term compatibility tests and flow compatibility testing; robustness of chemical control determined	Post-testing analysis of chemical impact; further supporting flow testing data
Operability	Develop principle concept of control objectives and control system; perform a failure modes and effects analysis; analyze dynamic properties such as flux profile, wind, and weather	Develop integrated control strategy; use prototypes to validate impact of control strategy	Sufficiently exercise capstone prototype to prove operating regimes' performance and impact for the commercial scale
Scalability	Moderate fidelity design of 1-5 MW system and low fidelity design of commercial concept; screening of manufacturing processes; understanding of system interfaces	Complete MW-scale design; moderate fidelity commercial system design	Complete cost estimate of commercial system based on learnings from testing
Cost	Identify formal cost modeling or methodology; fully disclose all assumptions; create full list of parameters to include in cost model; identify those parameters to be defined by work in the project and those defined externally; define initial ranges for parameters	Multiple quotes for most components; substantial reduction in possible ranges for most parameters based upon experimentation; verification and validation of the conclusions by an independent third party	Validate component costs via purchase orders; team and vendor create roadmap(s) to further component cost reductions, either via volume purchases or possible design revisions; validate performance functions at scale and on sun
System Integration	Explore and select options for physical interconnection with rest of system; define energy balance and state points of conceptual system	Determine final form of MW-scale physical integration; assess risks of physical integration at the commercial scale; consider annual variance in system state points	Directly show reliability of system interconnects either with on-sun testing or in parallel testing campaign; determine theoretical hourly performance of system over a year
Manufacturability	Identify and select viable commercial-scale manufacturing concepts based on cost and repeatability	Perform prototype manufacture by commercial-scale viable processes to the extent possible; develop design for manufacture process	Vendor/manufacture engineer's (process) and product revision schematics; document detailed impact on cost
Market Adoptability	Complete technoeconomic analysis; acquire feedback from commercial stakeholders	Complete detailed cost study and optimization influencing design	Commercialization partner involved in project; identify initial market adoption to be pursued; complete broad market adoption studies

iii. Topic Area 3: PTES: Pumped Thermal Energy Storage

Projects in this topic area will advance PTES technologies that are able to use electricity to charge thermal energy storage, either as standalone systems or integrated with CSP plants. In particular, this topic area seeks to increase the TRL and manufacturing readiness level (MRL)[77] of key PTES components, such as compressors and heat exchangers, to meet technoeconomic requirements for thermal energy storage.

Background

As the U.S. electric power system continues to evolve toward improved affordability, reliability, and resiliency, flexible energy storage is emerging as an important area needing innovation. Flexible, long-duration energy storage capable of storing and delivering 10 or more hours of power will be particularly important as the deployment of variable renewable energy ramps up to meet the U.S. goal of a carbon-free electric grid by 2035. DOE's recently announced Energy Storage Grand Challenge recognizes this need and has created a framework for developing ambitious goals to put the nation at the forefront of developing next-generation storage technologies.[78]

Existing commercial CSP plants with TES have demonstrated the viability of thermal storage to be responsive to grid needs, particularly for long durations of daily storage, up to 17 hours, that are not currently economically viable with conventional battery storage technologies like lithium-ion batteries. In particular, thermal systems are able to decouple the storage capacity component (e.g., molten salt stored in tanks) from the power-generating component (heat engine). This allows system designers to increase marginal storage capacity, or duration, by only increasing the size of the storage tank and without having to build additional generating capacity. While the modular nature of batteries has been attractive to help the technology rapidly scale, the intrinsic inability to decouple duration from power has, so far, limited most commercial application of the technology to four hours or less.

TES systems can be charged several ways. In CSP plants, TES is typically charged directly or indirectly by heating up a heat transfer fluid (HTF) or TES medium with sunlight. However, to increase flexibility of TES systems and improve their value to the grid, TES media can also be heated by an electric input. Simplistically, this can be done through a conventional resistive heater, but overall system efficiency can be increased by instead using an electric-driven compressor, or heat pump, to increase the temperature of the

[77] Section 2.3 of U.S. Department of Defense Manufacturing Readiness Levels Deskbook (DOD 2017).
[78] DOE. Energy Storage Grand Challenge. https://www.energy.gov/energy-storage-grand-challenge/energy-storage-grand-challenge.

system, in a PTES system. PTES systems are therefore composed of two coupled thermodynamic cycles:

1) **Heat Engine Power Cycle:** Converts thermal energy from a high-temperature source to mechanical work output, like the rotational momentum in a turbine-generator
2) **Heat Pump Cycle:** Converts input work and moves heat between a low-temperature and a high-temperature reservoir(s).

Thermodynamic cycle performance of the heat engine is defined using thermal efficiency, η_{th}, the ratio of net work output, W_{output}, to heat addition, Q_H.

$$\eta_{th} = \frac{W_{output}}{Q_H} \tag{1}$$

Heat pumps can be described using coefficient of performance, COP_{HP}, which is the ratio of heat input to the high-temperature reservoir, Q_H, to the net work input required, $W_{net,in}$; however, the COP can also be defined as heat rejected to cold reservoir over net work input.

$$COP_{HP} = \frac{Q_H}{W_{input}} \tag{2}$$

To evaluate the total system performance of an energy storage technology, an important performance metric is round-trip efficiency (RTE), which can be expressed in terms of the thermodynamic variables of the system, as the overall efficiency of the PTES system (η_{PTES}).

$$RTE = \eta_{PTES} = \frac{W_{output}}{W_{input}} = \frac{Q_H}{W_{input}} \cdot \frac{W_{output}}{Q_H} = COP_{HP} \cdot \eta_{th} \tag{3}$$

RTE will always be less than 1 because the efficiency of real systems is impacted by heat-exchange temperature approaches, radiative loss, pressure losses in piping and equipment, efficiency of turbomachinery, mechanical losses in gearboxes, and losses in the electrical machines. Simply, RTE can be expressed as a comparison of the energy input during the charging process and energy output during the discharging process:

$$RTE = \frac{Power_{net,out} * Duration\_Discharge}{Power_{gross,in} * Duration\_Charge} \tag{4}$$

For practical systems, factors that lead to high engine efficiency, like high temperature, tend to improve RTE, but this trend is limited because the COP of the heat pump tends to degrade with increased temperature. Nevertheless, higher temperatures, and therefore higher cycle efficiencies, may have an impact on the mass and volume of TES required, which would impact capital costs. An optimal temperature, based on cost and performance criteria is dependent on the form of PTES considered. These potential benefits should be carefully considered against the cost and performance limitations of higher temperatures.

Cost and Performance Target Metrics

Applicants[79] should justify their innovation based on a preliminary technoeconomic analysis illustrating market relevance of their technology, if their proposed work is successful. This analysis should include cost and performance targets that show advancement over the state of the art for the component under consideration, while being mindful of overall cycle costs and technical targets. Projects should be prepared to update and refine these analyses over the course of work.

Costs considered can be expressed as overall capital costs (including all turbomachinery, heat exchange, TES components, balance-of-plant, and installation/construction costs), operational costs, and/or a levelized cost of storage (LCOS). Performance metrics may include RTE, subcomponent efficiency, response time (for charge and discharge), component lifetime, among others, as appropriate.

LCOS[80] in particular is a key metric to describe the economic performance of a storage system:

$$LCOS = \left[\left(\frac{1}{RTE} - 1\right) P_c \sum_{t=1}^{T} \frac{n_c(t)}{(1+r)^t} + \sum_{t=1}^{T} \frac{O\&M(t)}{(1+r)^t} + \left(\frac{C_E}{\eta_d} + \frac{C_p}{d}\right)\right] \times \left[\sum_{t=1}^{T} \frac{n_c(t)}{(1+r)^t}\right]^{-1} \quad (3)$$

In the above equation, the first field represents the levelized cost per cycle of efficiency loss (as shown by RTE -1); the next field is the levelized cost per cycle of O&M; the last field is the installed cost per cycle of storage system capital and is composed of a term for storage capacity and a separate term for the power-related components. Improvements in LCOS can be made by increasing RTE, reducing O&M cost, reducing capital cost of TES and thermodynamic cycles, and increasing discharge efficiency and duration of discharge. However, LCOS is best represented when comparing technologies with similar storage capacities and grid-service functions.

The levelized cost of energy is the sum of levelized cost of storage and cost of purchased electricity and represents the discharge cost for a storage system:

$$LCOE = LCOS + P_c \quad (4)$$

[79] SETO. "How to Apply for a Funding Opportunity (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding.

[80] DAYS Program Overview, retrieved 07/06/2020 from https://arpa-e.energy.gov/sites/default/files/documents/files/DAYS_ProgramOverview_FINAL.pdf.

Table 5. *Definition of terms in Equation 5*

Variable	Definition
RTE	Round-trip efficiency of PTES, %
P_c	Input electricity price while charging, ¢/kWh
r	Discount Rate, %
T	System lifetime in years
$n_c(t)$	Total full charge-discharge cycles the system performs over time interval t
O&M(t)	Variable and fixed O&M cost in $/kWh
C_E	Capital cost of energy-related components in $/kWh
η_d	Discharge efficiency of power block, %
C_p	Capital cost of power-related components in $/kW
d	Storage duration at rated power, hours
LCOS	Levelized cost of storage, ¢/kWh

The primary cost metric to be considered will depend on markets under consideration for the technology. For example, capital costs may matter more than LCOS in capacity markets or applications with few lifetime charge/discharge cycles but ensure reliability, like in power-supply backup for critical infrastructure. For other markets, such as real-time markets on the bulk power system and ancillary service markets, the other economic parameters may dominate. This FOA does not define the specific application of PTES, but applicants should clearly justify their chosen application target and technoeconomic metrics.

Since standardized designs of PTES systems do not exist, an example list of equipment that can be considered for the system is presented here, along with a discussion of the technoeconomic targets. Table 6, below, suggests potential performance targets, which are primarily based on SETO's targets for components of CSP and sCO_2-based power cycles. Applicants must carefully consider the targeted performance metrics for their proposed components and be cognizant of the total capital cost and performance of the integrated PTES system.

Table 6. *Potential Technoeconomic Targets for PTES cycles*

Component	Performance targets
Charging compressor	ΔP sufficient to attain hot temperature of 565°C Efficiency > 85% Cost < 100 $/kW$_e$ of compression
Recuperator(s)	Effectiveness > 92% Cost < 200 $/kW$_e$ cycle output
Primary heat exchangers	Effectiveness > 92% Capital cost < 150 $/kW$_{th}$
Heat rejection	Effectiveness > 92% Total cost < 100 $/kW$_e$ Integration with precoolers to transfer heat to and from ambient or cold storage
TES	Energetic efficiency, ≥ 99%
	Exergetic efficiency ≥ 95%
	Capital cost ≤ 15 $/kWh$_{th}$ Temperature = 570-600 °C
Startup/Shutdown	< 15 minutes

SETO is interested in projects that advance PTES systems for hybridization with existing CSP plant designs and standalone PTES systems. Three possible methods of PTES may be considered:

A. PTES using ideal gases like argon, possibly with hot and cold storage;
B. PTES using real fluids like sCO_2, using existing or new hot stores, with or without a cold store;
C. PTES using real fluids for subcritical or transcritical cycles.

First the two cycles, (A) ideal gas cycles and (B) real gas cycles, with or without phase change, are discussed. sCO_2 is considered as an example of real gas.

Ideal Gas Cycles

The basic ideal gas system is composed of one charging cycle and one discharging cycle, with at least one hot heat exchanger, one or more recuperators, at least one heat rejection (to the ambient), and possibly one cold heat exchanger for cold storage. Since monatomic gases have the highest specific heat ratio, they have been used in ideal gas systems, and argon is considered a reasonable choice because it is available and economical. Helium is an alternate but requires more compression and more stages, and therefore, higher capital cost. The only successful example employing argon makes use of reciprocating turbomachinery that limits efficiency.[81] If restricted to temperatures compatible with conventional stainless-steel piping and containment (~550°C), the pressure ratio for the system is approximately 30 and maximum pressure is of the order of 35 bars (500 psig). Significant technical improvements would be required in the performance of compressors, recuperators, and hot and cold heat exchangers to attain these parameters.

Real Gas Cycles

Real fluids, like sCO_2, will need high pressure ratios to avoid transcritical operation. The difference between sCO_2 supercritical and transcritical cycles is the need for an additional pump before the compressor. However, development needs include high temperature sCO_2 compressors and solutions to reduce the number of required heat exchangers by reusing the hot store and cold store heat exchangers and recuperators if the charge and discharge times are maintained separately.

For both types of cycles, integration with current-generation CSP plants is of interest. If proposing a CSP-hybrid system, applicants should quantify the change in levelized cost of energy (ΔLCOE) and change in capacity factor, relative to a traditional CSP plant without a heat pump. However, if economics permit, applicants can explore thermodynamic conditions beyond current generation CSP cycles.

In summary, SETO seeks to advance innovations in PTES systems and components that can lead to achieving overall cycle capital and operational cost targets, levelized cost of electricity/storage targets, and round-trip efficiency that would be competitive in current and future markets. Project proposals should aim to increase the TRL of these technologies from ~3 to 6 and a MRL level 2/3 to 6, readying these technologies for use by developers in their proposed plants after testing and further scale-up.

Areas of Interest

Applications to this topic must address the research challenges focused on near-term impactful projects. Broad technoeconomic targets for PTES are provided in Table 6, above. The areas of interest include but are not limited to the following:

- **System Components for Ideal or Real Gas PTES**
  Ideal gas PTES cycles that use monoatomic argon or helium require special turbomachinery and consolidation of recuperators and heat exchangers to be

[81] White, G. Parks, and C. N. Markides. "Thermodynamic analysis of pumped thermal electricity storage," *Appl. Therm. Eng.,* vol. 53, no. 2, pp. 291–298, May 2013. Also see: Frutchi, Hans Ulrich. *Closed Cycle Gas Turbines: Operating Experience and Future Potential.* ASME Press 2005.

able to achieve the technoeconomic targets described in this topic. PTES heat pumps for sCO_2 or other real gases may require the development of compressors and consolidation of recuperators and heat exchangers to be able to achieve the technoeconomic targets described in this topic. Research of interest may include the development of compressors, recuperators and heat exchangers that can transfer heat bidirectionally (to reduce capital costs) and other subcomponents that form part of the system but are not explicitly mentioned in this document. Applicants should clearly lay out a path for attaining the overall LCOS, capital cost, and RTE goals, noting that different combinations of capital costs, operating costs, and heat pump and discharge cycle efficiencies can lead to the required LCOS.

For both ideal and real gas PTES systems, developing heat pump compressors of large flow capacity that can attain 570°C presents a significant challenge. Both axial compressors and integral geared compressors tend to be expensive to build and test. Other concepts in equipment development could include integration of multiple heat exchanger services to realize some cost advantage and performance. Integration of heat exchange services may eliminate the need for headers and interconnecting piping between some sections of heat exchange. Such heat exchange integration is common in the chemical industry. It may be economically advantageous to share equipment between charging and discharging cycles. If heat exchangers are a substantial part of the cost of the PTES system, there may be advantages to sharing them and having them transfer heat bidirectionally, or using combinations of isolation and check valves to direct fluids accordingly.

- **Components for PTES System Integration with CSP Plants**
  The goals for this area of interest are similar to those in the area described above, but the focus should be on integration with the current generation steam Rankine cycle–based CSP plants so that the value and flexibility of CSP plants can be improved. Adding a charging heat pump system using low-cost electricity from the grid, or a closely coupled variable renewable generator, may significantly increase a CSP plant's ability to deliver electricity on demand. In addition, enabling electric charging of TES may allow plant designers to significantly lower capital costs by reducing the size of the solar field while maintaining a high capacity factor.

  Applications may use energy costs (LCOS, LCOE) or assumptions regarding capacity cost (from capital cost of power cycle and TES in Table 6) to establish their design goals. However, all applications should clearly specify technoeconomic targets and explain how the targets of capacity costs or energy costs can be achieved through the proposed research and development.

iv. Topic Area 4: CSP PERFORM & REFORM

This topic seeks projects to advance development of technologies, operational strategies, and technical standards to improve reliability, enhance value, and lower costs for future CSP plants through validation at existing parabolic trough and power tower plants.

Background

Nearly 7 GW of CSP has been deployed worldwide, with the total capacity of installed plants increasing by almost six times from 2010 to 2019. The CSP industry has had opportunities to iteratively improve through multiple commercial deployment cycles. The CSP stakeholder community is now well positioned to take stock of lessons learned, best practices, and priority areas for further technology development.

To document this progress, SETO supported a consortium of researchers, led by the National Renewable Energy Laboratory, to publish the *Concentrating Solar Power Best Practices Study*[82] in 2020. This report solicited project information from owners, operators, and EPC contractors, independent engineers, and other stakeholders of parabolic trough and tower plants. The study resulted in the identification of best practices and lessons learned from the engineering, construction, commissioning, operations and maintenance (O&M) of existing CSP systems. However, in several areas, it was not possible to identify industry-established best practices or opportunities to develop performance and cost enhancements over the current state of the art—equipment reliability, in particular. The two topics below seek solutions and improvements in system-level designs, processes, and models (Topic Area 4a) and R&D in components that can improve performance and reliability of CSP plants (Topic Area 4b).

Topic Area 4a: CSP Process Enhancement and Refinement for Operations, Reliability, and Maintenance (CSP: PERFORM)

Projects in this topic area will focus on improving the reliability, operability, and productivity of systems, processes, and designs of existing CSP technologies. This topic area is intended to further develop and evaluate solutions to reliability and performance issues that have been identified in existing CSP plants.

To achieve a carbon-free electric grid by 2035 and enable effective planning and deployment, it is essential that renewable energy technologies be reliably designed, built, and operated. The development of reliable and affordable CSP technology for the

[82] Mehos, Mark, et al. *Concentrating Solar-Thermal Power (CSP) Best Practices Study.* NREL, NREL/TP-5500-75763, 2020.

United States can be accelerated by advancing research to overcome issues that adversely affect operability, reliability, and performance in CSP facilities. These solutions and practices have the potential to reduce operating costs and increase revenues in existing CSP facilities and planned near-term CSP projects. Tools such as metrology or modeling that are specific to CSP can support successful ongoing operation and maintenance of CSP plants. Further, industry codes and standards, design guides, and technical committees can speed the adoption of solutions throughout the industry.

Many innovations relevant to this topic inherently involve considerations of balancing higher capital costs to lower ongoing operational costs and complexity, and vice-versa. Therefore, while reducing LCOE should be an ultimate cost metric considered to weigh these trade-offs, LCOE may be too coarse to appropriately quantify potential benefits. Applicants should consider other, more specific metrics, including measures like return on investment or payback period, to justify commercial relevance. Additional metrics that may be appropriate to demonstrate value include total plant efficiency and plant availability, profitability, or operability (e.g., reduced startup times). Qualitative metrics may also be considered, including a demonstrated improvement in deployability, market versatility, or bankability, to make meaningful reductions in the barriers to the deployment of CSP in the United States. Applicants should quantitatively justify the potential benefit of proposed work.

All applicants must clearly define a current industry baseline to compare the proposed innovation against and justify how their proposed work will benefit the CSP industry at large; solutions that are applicable only to unique or unusual plant situations and not scalable to a large portion of the industry are not of interest. Applicants must also carefully consider the composition of their proposed project team. Close participation with entities that have considerable experience in the planning, engineering, construction, and operation of multiple CSP plants, such as EPC contractors, plant owners, and experienced operators, will likely be required to achieve impactful results.

Areas of Interest

The areas below represent some key needs identified in the best-practices report and are of particular interest for detailed study, although other areas of research may be proposed. Applications[83] to this topic must address the research challenges with a focus on near-term project impact. The areas of interest include but are not limited to the following:

- CSP Plant Modeling and Data Sets:

[83] SETO. "How to Apply for a Funding Opportunity (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding.

Proposals of interest could include improved performance modeling techniques and software to provide both real-time operating guidance and longer-term operational planning, possibly including start-ups, shutdowns, TES management, power generation, and maintenance planning; performance modeling for technoeconomic analysis, project development, performance testing, or transient operation evaluation; and advanced algorithms or software or data analysis techniques to support decision-making efforts of operators, owners, and plant designers.

Of particular interest are solutions that gather available plant data and other information, package real operating data into publicly available full or partial data sets, provide added-value analysis, enable improved model development and validation, and develop case studies or otherwise facilitate the exchange and sharing of information to benefit CSP plants and allow data-based assessments of CSP performance and reliability. While some plant data may need to be anonymized or truncated to allow public release, even partial data sets representative of a variety of operating conditions and set-points may be valuable and impactful for model validation and analysis of opportunities for improved plant performance.

- Molten Nitrate Salt TES Tank Design Practices:
  Several deployments of nitrate salt TES have shown reliability concerns due to a handful of common engineering design issues, including tank floor buckling, stress concentrations, temperature management, and soil degradation. A comprehensive design standard does not exist to help tank-design engineers address these issues. To date, the API 650 Code[84] is most commonly used, although the code is not intended to address the high temperatures associated with molten nitrate salts. Successful applicants will identify the best engineering design practices for molten nitrate salt tanks that lead to the development of a design standard for the industry. In addition to the specific nitrate salt design concerns, the effort should also consider the basic tank design issues associated with overpressure, pressure relief, leakage, vortex formation, structural support, overfilling, and other common tank design and operation issues. Applicants should also identify a clear, well-planned dissemination and engagement strategy to enable adoption of new codes or standards by key stakeholders.

- Operator Training:
  Conduct studies and develop tools to establish best practices designed to lower O&M costs, including operator training programs, preventive maintenance programs, predictive maintenance programs, non-destructive evaluation (NDE)

[84] American Petroleum Institute, 2013, "Welded Tanks for Oil Storage," 650.

testing, or outage planning. Conduct research focused on special topics of operation, including transients, startup, and emergency operation. Best practices with respect to CSP plant initial startup might also be addressed under this topic, such as system cleaning and flushing, system commissioning, plant energization, and EPC contractor lessons learned.

- Plant Automation and Control Systems:
  Control algorithms in the plant distributed control system (DCS) and other control systems do not have well-established industry practices for CSP-specific systems. Of interest are automation solutions to reduce O&M costs and improve plant reliability, availability, efficiency, and profitability. This is a broad topic area that includes control systems, software packages, commissioning efforts, control algorithms, and lessons learned. Artificial intelligence, machine learning, distributed control systems, control logic, plant instrumentation, and other control methods are also of interest for this application. Innovations may address plant operating systems or other less critical systems (e.g., predictive maintenance, etc.) that significantly affect CSP plant operating costs.

- Technical Specifications:
  Lessons from past efforts can guide planning and design of CSP plants and systems. Proposals should identify case studies and statistical data that supports the development of technical designs and specifications for future CSP plants. Efforts should include analysis of the potential O&M cost savings of key features relative to upfront capital investments. The effort should focus on developing industry design specifications that further define and enhance existing technical specifications for the CSP plant as a whole and/or CSP components.

Topic Area 4b: CSP Research in Equipment For Optimized and Reliable Machinery (CSP: REFORM)

Projects in this topic area will focus on improving the design and operation of CSP plants by developing components and equipment for commercially relevant CSP systems that utilize conventional steam Rankine power cycles.

Background
To achieve the target of $0.05/kWh for CSP with more than 12 hours of TES, SETO-supported research has primarily focused on high-temperature systems and components that will enable solar heat to be collected, stored, and used at temperatures exceeding 565°C, the maximum temperature of conventional molten nitrate salt technology. In particular, SETO has targeted the development of Gen3 CSP systems that aim to deliver heat to an sCO_2-based power cycle at 700°C or higher. While Gen3 systems are the primary strategy SETO is pursuing to meet market-competitive

LCOE goals, there may be opportunities to apply lessons learned in developing these high-temperature components to lower temperature systems for molten nitrate salts, operating between 275°C and 565°C. Near-term, low-risk applications may help to accelerate commercial de-risking of novel component designs, new manufacturing technologies, or other innovations. In addition, developing technology and components for the current generation of CSP technology can support the growth of a supply chain that advances future Gen3 systems.

SETO has supported the development of a number of innovations in heat exchangers, receivers, TES systems, materials, and manufacturing processes. This topic area seeks to apply these innovations in developed systems, materials, equipment, and manufacturing directly to CSP plants that use existing steam-Rankine technology, to improve reliability and/or decrease LCOE. While present-day commercial plants use nitrate salts as HTF, this topic area solicits research in components for systems that use solid particles as heat transfer and TES media for steam-Rankine cycles.

Applicants[85] should carefully consider appropriate quantitative metrics to support their proposed innovation and justify their proposed work in comparison to clearly defined baselines in the CSP and power generation industries.

Areas of Interest

Applications to this topic must address research challenges that improve the productivity or operability of CSP plants based on steam Rankine power cycles. Component development, manufacturing processes, and materials proposed should focus on cost reduction and performance improvements of these plants. Concepts relevant to plant designs that use heat transfer and thermal storage media other than molten nitrate salts are welcome, even though no existing commercial plants incorporate such pathways. The areas of interest include but are not limited to the following:

Improvements in TES Systems for Molten Salts or Particles, Including Reconfiguration, Relocation, or Redesign of Pumps/Elevators:

Current state-of-the-art TES systems make use of a carbon steel cold tank (at ~295°C) and a stainless-steel hot tank (at ~565°C) with roof-mounted long shaft pumps. The cost of this system for tower-based systems, including the two tanks, salt, and the hot salt pump, is estimated at approximately $\$26/kWh_{th}$.[86] To achieve the SETO target of

[85] SETO. "How to Apply for a Funding Opportunity (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding.

[86] Greg Glatzmaier. "Developing a Cost Model and Methodology to Estimate Capital Costs for Thermal Energy Storage." NREL/TP-5500-53066, December 2011.

$15/kWh$_{th}$, a number of innovations in TES design are needed, some of which have been explored for high-temperature Gen3 applications:

- Stainless-steel hot tanks have demonstrated operational challenges, in part due to both differential thermal expansion between soil/foundation and steel wall, and stress-relaxation cracking issues. Novel tank wall concepts, materials, or interface configurations may improve reliability of this key component. In particular, internally insulated carbon steel tanks have been considered, but a robust design compatible with hot molten nitrate salt has not yet been demonstrated.
- Relocation of pumps away from roof-mounting may allow for the design of taller tanks or more spherical tanks that are more structurally robust.
- While long-shafted pumps have generally functioned robustly in service, multiple improvements are possible to improve cost. While relocation of the pump to the ground may allow simplification of support structures, such a redesign will likely require new designs for a leak-proof salt pump with innovative sealing and seal cooling.
- Advances in novel manufacturing techniques, like high-toughness coatings or metal casting methodologies, developed for high-temperature applications, may also be relevant to molten nitrate salt pumps, enabling significant reductions in pump costs.
- Another option available for operational savings for cold salt pumps is energy recovery from the flow down the tower. While technology for energy recovery from reverse osmosis membranes exists and is used in industry, recovery of energy from the downcomer has not been attempted in CSP industry due to cost concerns.
- Particles as HTF and TES are being studied as a part of Gen3. However, balance of systems components for particle TES such as valves, elevators, and heat exchangers for heat transfer to water are not readily available and require further development. Development of particle TES components for temperatures relevant to steam-Rankine power cycles are also of interest.

Alternate Designs for Steam Generation Systems (SGS) and Supporting Structures

Present-day SGS systems typically consist of a superheater, reheater, evaporator, steam drum, and economizer. These heat exchangers are typically shell-and-tube designs, seal-welded to the tube sheets and then plastically deformed, to accommodate cyclic operation. Their performance in molten salt tower plants have suffered from cycling-related challenges.错误！未定义书签。 Additionally, the variability of realistic operation, including inadequate control over blending hot and cold salt during startup, has led to rates of temperature change and thermal cycling not supported by vendor design. Several innovations in the SGS system may significantly improve reliability:

- Printed circuit heat exchangers have become a promising alternative to shell and tube heat exchangers in a number of applications. The low cost, high power/weight ratio and simplicity of inlet and exit nozzle designs are appealing features in a variety of applications. Innovative design of a compact economizer-evaporator-superheater-reheater and insights from simulated startup testing using hot/cold molten salt mixtures may significantly reduce risks and improve reliability of future CSP plants.
- Integration of heat exchange components may eliminate the need for headers and interconnecting piping between some sections of heat exchangers. Such integration is common in liquefied natural gas applications where techniques have been developed for both plate-fin and spiral-wound shell-and-tube type heat exchangers.
- Innovative compact heat exchangers may allow for designs that avoid the use of hot and cold salt blends to preheat components, and instead allow the incorporation of recuperators and ceramic electric heaters. Novel designs could meaningfully improve performance during daily startups and transient operation.

Innovative Tower Design and Construction

Present-day molten salt towers are concrete structures 140-180 meters (m) high, made using cast-in-place concrete, poured using proprietary formwork. Innovations in tower construction have not been significantly explored, due to the relative immaturity of the CSP tower industry. However, wind turbine developers, motivated by an annual demand for a large number of towers (more than 5,000 per year), have aggressively pursued tower design innovations. Wind turbine developers have also aggressively explored increasing hub height from 80 m to 140-180 m, comparable to CSP tower heights. New proposed designs include fully concrete field-cast towers; hybrid, factory-cast concrete and steel towers; large diameter steel towers; and lattice towers. The lattice tower concept is especially promising with cost targets of $500,000[87] for a 140 m height. While simple repurposing of wind tower designs, topped with a receiver and fitted with piping, may be inadequate for CSP molten salt towers, the basic modularity of wind tower section assembly could be a basis for new, innovative CSP tower construction. This topic area solicits novel tower designs derived from advances in other industries that can reduce the cost of construction to under $2 million for 140-180 m in height.

[87] Lantz at al. "Increasing Wind Turbine Tower Heights: Opportunities and Challenges." NREL/TP-5000-73629

v. Topic Area 5: Small Innovative Projects in Solar (SIPS): PV and CSP

SIPS for PV and CSP is an agile funding vehicle for SETO investments with two major aims: to investigate higher-risk ideas that address a major technology barrier or open the possibility of a novel concept, and to attract new entrants into the applied solar R&D community. This topic area will use a simplified application process, described in Section IV.A of this FOA. Applicants are required to submit a Letter of Intent, but Concept Papers are not required.

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

All applications must describe the following:

1. The current understanding of the novel science, technology, concept, or component
2. How successful research would change the state of the art and how it could impact key technoeconomic metrics
3. What new scientific or engineering understanding of the technology, concept, or component 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

New principal investigators, especially early-career researchers who have never applied or have been awarded in SETO portfolio, are encouraged to apply.[88]

Topic Area 5a. SIPS PV

Projects in this topic area will focus on new and emerging areas of PV research that can produce significant results within the first year of performance and, if successful, lay the foundation for continued research. These projects should aim to significantly lower costs with a focus on improving the power conversion efficiency, fielded energy output, reuse and recycling of system components, service lifetime, and manufacturability of PV technologies.

PV SIPS projects should collect 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

[88] SETO. "How to Apply for a Funding Opportunity (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding.

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 Topic Area 1: 50-Year Service Life PV Systems (PV-50): Photovoltaics Hardware Research, Figure 4.

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 work funded[89] by SETO's PV subprogram are of particular interest.

Areas of Interest

Successful applicants will propose projects that support an installed cost of solar of $0.02 per kWh by addressing the technical challenges described in Topic Area 1: 50-Year Service Life PV Systems (PV-50).

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 5b. SIPS CSP

Projects in this topic area will focus on innovative and novel ideas that will dramatically lower the cost of CSP technologies to produce power or industrial heat. If successful, the technology should be well positioned to move to the next stage of research and development after one year.

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).[90] All aspects of CSP plants with thermal energy storage, as well as SIPH

[89] SETO. "How to Apply for a Funding Opportunity (FOA)." https://www.energy.gov/eere/solar/how-to-apply-for-funding.
[90] SETO 2018 Portfolio Book. https://www.energy.gov/sites/prod/files/2018/02/f48/2018%20SETO%20Portfolio%20Book.pdf.

innovations, are of interest. Ideas aligned with the goals of previous SETO CSP solicitations are encouraged.[91] One pathway to SETO's CSP goal is shown in Figure 8, below. 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.

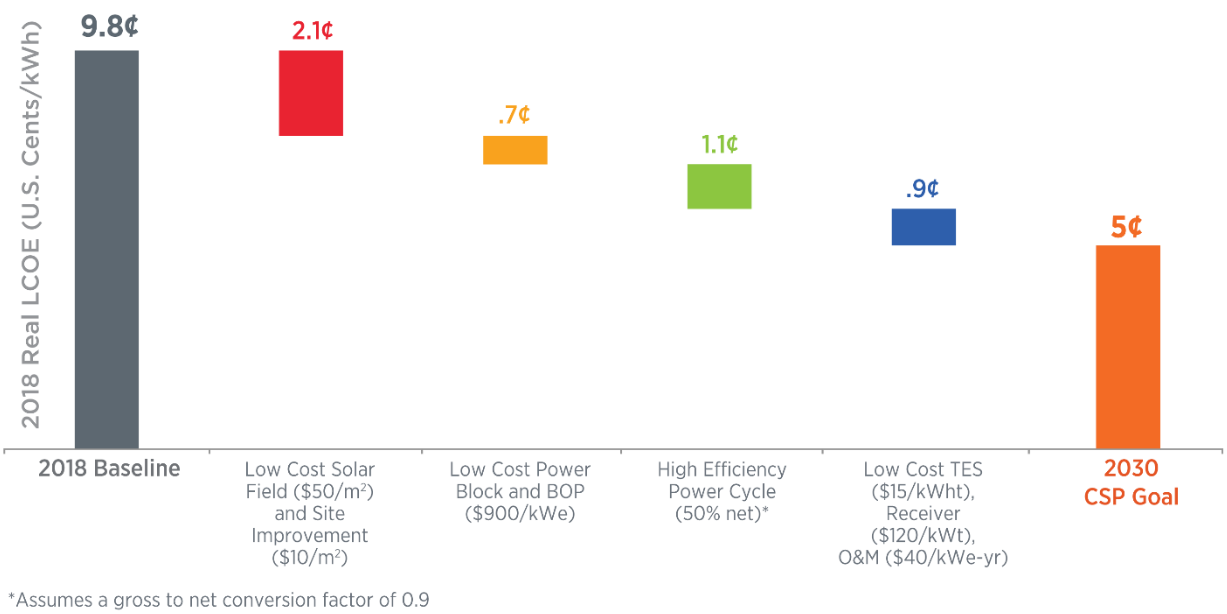

Figure 8. *A Pathway to 5¢/kWh CSP LCOE*

To help focus the tasks of these agile research efforts, the application should clearly describe a central hypothesis the project is testing. The explanation of the proposed work should lay out a research plan that can strongly support or disprove the key hypothesis. If successful, the technology should be well positioned to move to the next stage of research and development, whether that is fabrication of a prototype, integration within a system, a high-fidelity 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) 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.

Areas of Interest This list is not exhaustive. Applications that address areas not listed here will still be considered for funding if they address the broader goals of Topic Area 5b.

[91] SETO Solar Energy Research Database. https://www.energy.gov/eere/solar/solar-projects-map.

- Inexpensive collector materials: SETO seeks projects that will develop low-cost materials and manufacturing innovations for individual components or assembly processes to reduce the installed cost of heliostats or other solar collectors, potentially including innovations relevant to support structure, drives, reflector facets, or foundations. Applicants should explicitly describe how their innovation may reduce capital costs in terms of $/m^2 of reflector area while still considering impacts on efficiency, lifetime, reliability, or other O&M impacts.
- Reliable additive manufacturing for CSP: Additive manufacturing has emerged as an attractive method to fabricate novel CSP components with potentially improved performance relative to conventional designs. However, reproducibility of these results and reliability of additively manufactured components remains a risk, leaving significant gaps in the robust understanding of correlations between material and process parameters and component performance.
- Solar thermochemical and solar industrial process heat applications road mapping: Complementary to Topic 2: SOLAR R&R, SETO seeks analytical studies describing the value proposition and market potential of specific solar thermochemical pathways for the production of fuels and other chemical commodities. SETO has supported analysis to understand the market potential of solar-thermal integration in industrial processes,[92] but significant gaps remain in process-level descriptions of the research barriers for cost-effective systems.
- Metrology and methods for CSP research: Tools and methods for monitoring or determining optical, thermal, mechanical, and chemical properties are sought for research and commercial plant environments. These can impact the risk of novel technology development or the bankability of performance and lifetime of CSP plant operations. Methods include development of robust formalisms and acceptance criteria that researchers, designers, or operators should employ to declare data bankable and reliable.
- Permanent magnet bearings for sCO_2 power cycle turbomachinery: Gas and magnetic bearings have been increasingly applied to integrate compressors, turbines, and generators in other industries. Similarly, large permanent magnet generators that can integrate with expanders without recourse to large gearboxes have been developed for wind power. These bearings have reduced capital and operating requirements by eliminating lubrication subsystems and

[92] Schoeneberger, C., McMillan, C., Kurup, P., Akar, S., Margolis, R., & Masanet, E. (2020). "Solar for industrial process heat: A review of technologies, analysis approaches, and potential applications in the United States." *Energy*, 118083.

reducing maintenance requirements. However, specific challenges for sCO_2 machinery for CSP, including high rotational speed, significant heat generation, and high operating temperature, have prevented CSP-relevant application of the technology.

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

C. Applications Specifically Not of Interest

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

- Applications that fall outside the technical parameters specified in Section I.A and I.B of the FOA.
- Applications for proposed technologies that are not based on sound scientific principles (e.g., violates the laws of thermodynamics).

D. Authorizing Statutes

The programmatic authorizing statute is EPACT 2005, Section 931 (a)(2)(A).

Awards made under this announcement will fall under the purview of 2 Code of Federal Regulation (CFR) Part 200 as amended by 2 CFR Part 910.

II. Award Information

A. Award Overview

i. Estimated Funding

EERE expects to make a total of approximately $39,500,000 of federal funding available for new awards under this FOA, subject to the availability of appropriated funds. EERE anticipates making approximately 31 to 54 awards under this FOA. EERE may issue one, multiple, or no awards. Individual awards may vary between $300,000 and $5,000,000.

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

Topic Area Number	Topic Area Title	Anticipated Number of Awards	Anticipated Minimum Award Size for Any One Individual Award (Fed Share)	Anticipated Maximum Award Size for Any One Individual Award (Fed Share)	Approximate Total Federal Funding Available for All Awards	Anticipated Period of Performance (months)
1	50-Year Service Life PV Systems (PV-50)	1-4	$750,000	$3,750,000	$4,500,000	24-36
2	SOLAR R&R: Scalable Outputs for Leveraging Advanced Research on Receivers & Reactors	3-7	$1,000,000	$5,000,000	$11,000,000	12-36
3	PTES: Pumped Thermal Energy Storage	4-9	$500,000	$3,000,000	$11,000,000	24-36
4a	CSP PERFORM: Process Enhancement and Refinement For Operations, Reliability, and Maintenance	3-6	$400,000	$2,000,000	$4,000,000	24-36
4b	CSP REFORM: Research in Equipment For Optimized and Reliable Machinery	3-6	$400,000	$2,000,000	$4,000,000	24-36
5a	SIPS-PV	7-10	$300,000	$300,000	$2,000,000	12
5b	SIPS-CSP	10-13	$300,000	$400,000	$3,000,000	12-18

EERE may establish more than one budget period for each award and fund only the initial budget period(s). Funding for all budget periods, including the initial budget period, is not guaranteed. Before the expiration of the initial budget period(s), EERE may perform a down-select among different recipients and provide additional funding only to a subset of recipients.

ii. Period of Performance

EERE anticipates making awards that will run from 12 up to 36 months in length, comprising one or more budget periods. Project continuation will be contingent upon several elements, including satisfactory performance and Go/No-Go decision review. For a complete list, see Section VI.B.xii. At the Go/No-Go decision points, EERE will evaluate project performance, project schedule adherence, the extent milestone objectives are met, compliance with reporting requirements, and overall contribution to the program goals and objectives. As a result of this evaluation, EERE 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.

Topic Area Number	Topic Area Title	Estimated Duration of Award (months)
1	50-Year Service Life PV Systems (PV-50)	24-36
2	SOLAR R&R: Scalable Outputs for Leveraging Advanced Research on Receivers & Reactors	12-36
3	PTES: Pumped Thermal Energy Storage	24-36
4a	CSP PERFORM: Process Enhancement and Refinement For Operations, Reliability, and Maintenance	24-36
4b	CSP REFORM: Research in Equipment For Optimized and Reliable Machinery	24-36
5a	SIPS-PV	12
5b	SIPS-CSP	12-18

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. 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.

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.

Topic Area 1: DOE/NNSA FFRDCs and National Laboratories are eligible to apply for funding as a subrecipient, but are not eligible to apply as a prime recipient.

Topic Areas 2, 3, 4a, 4b, 5a, and 5b: DOE/NNSA FFRDCs and National Laboratories are eligible to apply for funding as a prime recipient or subrecipient.

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.

Diverse entities such as, but not limited to: Minority Serving Institutions (MSIs), including Historically Black Colleges and Universities (HBCUs)/Other Minority Institutions (OMIs),[93] are eligible and encouraged to apply for funding as a prime recipient or subrecipient.

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

[93] Minority Serving Institutions (MSIs), including HBCUs/OMIs as educational entities recognized by the Office of Civil Rights (OCR), U.S. Department of Education, and identified on the OCR's Department of Education U.S. accredited postsecondary minorities' institution list. See https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html.

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; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

B. Cost Sharing

Topic Areas 1, 2, 3, 4a, and 4b: 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 research and development 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.) Projects are allowed to have both R&D components (tasks) and demonstration components (tasks), which will result in a blended cost share for the full project. Demonstration activities normally include the deployment and use of a technology outside the development environment, where it can interact with external systems in non-trivial manner.

Topic Areas 5a and 5b: The cost share must be at least 20% of the total allowable costs for research and development projects (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) 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.)

Topic Area Number	Topic Area Title	Cost Share Requirement
1	50-Year Service Life PV Systems (PV-50)	20% (R&D) 50% (demonstration)
2	SOLAR R&R: Scalable Outputs for Leveraging Advanced Research on Receivers & Reactors	20% (R&D) 50% (demonstration)
3	PTES: Pumped Thermal Energy Storage	20% (R&D) 50% (demonstration)
4a	CSP PERFORM: Process Enhancement and Refinement For Operations, Reliability, and Maintenance	20% (R&D) 50% (demonstration)
4b	CSP REFORM: Research in	20% (R&D)

	Equipment For Optimized and Reliable Machinery	50% (demonstration)
5a	SIPS-PV	20%
5b	SIPS-CSP	20%

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.

iii. Cost Share Types and Allowability

Every cost share contribution must be allowable under the applicable federal cost principles, as described in Section IV.J.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; or
- 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 cost sharing requirements.

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 (i.e., 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

Letters of Intent (required for all Topic Areas), Concept Papers (required only for Topic Areas 1, 2, 3, 4a, and 4b), Full Applications, and Replies to Reviewer Comments (encouraged for Topic Areas 1, 2, 3, 4a, and 4b) must meet all compliance criteria listed below or they will be considered noncompliant. EERE will not review or consider noncompliant submissions, including Letters of Intent, Concept Papers, Full Applications, and Replies to Reviewer Comments that were: submitted through means other than EERE Exchange; submitted after the applicable deadline; and/or submitted incomplete. EERE will not extend the submission deadline for applicants that fail to submit required information by the applicable deadline due to server/connection congestion.

Topic Area Number	Topic Area Title	Is Letter of Intent applicable?	Is Letter of Intent required?	Is Concept Paper applicable?	Are Replies to Reviewer comments applicable?
1	50-Year Service Life PV Systems (PV-50)	Yes	Yes	Yes	Yes
2	SOLAR R&R: Scalable Outputs for Leveraging Advanced Research on Receivers & Reactors	Yes	Yes	Yes	Yes
3	PTES: Pumped Thermal Energy Storage	Yes	Yes	Yes	Yes
4a	CSP PERFORM: Process Enhancement and Refinement For Operations, Reliability, and Maintenance	Yes	Yes	Yes	Yes
4b	CSP REFORM: Research in Equipment For Optimized and Reliable Machinery	Yes	Yes	Yes	Yes
5a	SIPS-PV	Yes	Yes	No	No
5b	SIPS-CSP	Yes	Yes	No	No

Compliance Criteria

i. Letters of Intent (required for all Topic Areas)

Letters of Intent are deemed compliant if:

- The applicant entered all required information and clicked the “Submit” button in EERE Exchange by the deadline stated in the FOA; and
- The Letter of Intent complies with the content and form requirements in Section IV.C of the FOA.

ii. Concept Papers (required for Topic Areas 1, 2, 3, 4a, and 4b)

Concept Papers are deemed compliant if:

- The applicant submitted a compliant Letter of Intent;
- 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.

iii. Full Applications

Full Applications are deemed compliant if:

- The applicant submitted a compliant Letter of Intent and Concept Paper;
- The Full 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.

iv. Replies to Reviewer Comments (encouraged for Topic Areas 1, 2, 3, 4a, and 4b)

Replies to Reviewer Comments are deemed compliant if:

- The Reply to Reviewer Comments complies with the content and form requirements in Section IV.F of the FOA; and
- The applicant successfully uploaded all required documents to EERE Exchange by the deadline stated in the FOA.

D. Responsiveness Criteria

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

E. Other Eligibility Requirements

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

A DOE/NNSA FFRDC is eligible to apply for funding under this FOA 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 (M&O) 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:

i. 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.

ii. 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.

iii. 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 (WP) system and non-DOE/NNSA FFRDC through an interagency agreement with the sponsoring agency.

iv. 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.

v. *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.

vi. *Limit on FFRDC Effort*
The scope of work to be performed by the FFRDC, when the FFRDC is a subrecipient, may not be more significant than the scope of work to be performed by the applicant.

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

Topic Areas 1, 2, 3, 4a, and 4b: An entity may submit more than one Concept Paper and Full Application to this FOA, provided that each application describes a unique, scientifically distinct project and provided that an eligible Concept Paper was submitted for each Full Application.

Topic Areas 5a and 5b: An entity may submit more than one Full Application to this FOA, provided that each application describes a unique, scientifically distinct project.

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

For Topic Areas 1, 2, 3, 4a, and 4b, the application process will include three phases: a Letter of Intent phase, a Concept Paper phase, and a Full Application phase. For Topic Areas 5a and 5b, the application process will include two phases: a Letter of Intent phase and a Full Application phase. **For topic areas that require a Concept Paper, only applicants who have submitted an eligible Concept Paper will be eligible to submit a Full Application**.

Topic Area(s)	Phase 1: Letter of Intent	Phase 2: Concept Paper	Phase 3: Full Application
Topic Areas 1, 2, 3, 4a, and 4b	Yes	Yes	Yes
Topic Areas 5a and 5b	Yes	No	Yes

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

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

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

- Each must be submitted in Adobe PDF format unless stated otherwise;
- Each must be written in English;
- All pages must be formatted to fit on 8.5 x 11 inch paper with margins not less than one inch on every side. Use Calibri typeface, a black font color, and a font size of 12 point or larger (except in figures or tables, which may be 10 point font). A symbol font may be used to insert Greek letters or special characters, but the font size requirement still applies. References must be included as footnotes or endnotes in a font size of 10 or larger. Footnotes and endnotes are counted toward the maximum page requirement;
- The Control Number must be prominently displayed on the upper right corner of the header of every page. Page numbers must be included in the footer of every page; and
- Each submission must not exceed the specified maximum page limit, including cover page, charts, graphs, maps, and photographs when printed using the formatting requirements set forth above and single spaced. If applicants exceed the maximum page lengths indicated below, EERE will

review only the authorized number of pages and disregard any additional pages.

Applicants are responsible for meeting each submission deadline. **Applicants are strongly encouraged to submit their Letters of Intent (required for all Topic Areas), Concept Papers (required for Topic Areas 1, 2, 3, 4a, and 4b), Full Applications (required for all Topic Areas), and Replies to Reviewer Comments (encouraged for Topic Areas 1, 2, 3, 4a, and 4b) at least 48 hours in advance of the submission deadline**. Under normal conditions (i.e., at least 48 hours in advance of the submission deadline), applicants should allow at least one hour to submit a Letter of Intent, Concept Paper, Full Application, or Reply to Reviewer Comments. Once the Letter of Intent, Concept Paper, Full Application, or Reply to Reviewer Comments is submitted in EERE Exchange, applicants may revise or update that submission until the expiration of the applicable deadline. If changes are made to any of these documents, the applicant must resubmit the Letter of Intent, Concept Paper, Full Application, or Reply to Reviewer Comments before the applicable deadline.

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

i. Additional Information on EERE Exchange

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

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

B. Application Form

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

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

TechnicalVolume_Part_1
TechnicalVolume_Part_2

C. Content and Form of the Letter of Intent

Applicants must submit a Letter of Intent by the specified due date and time to be eligible to submit a Concept Paper and Full Application. Letters of Intent 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 Letters of Intent (see Section III of the FOA).

Each applicant must provide the following information as part of the Letter of Intent:

- Project Title;
- Lead Organization;
- Organization Type (Business < 500 Employees; Business > 1000 Employees; Business 500-1000 Employees; FFRDC; Government-Owned, Government Operated; Non-Profit; University);
- Whether the application has been previously submitted to EERE;
- % of effort contributed by the Lead Organization;
- The Project Team, including:
  - The Principal Investigator for the prime recipient;
  - Team Members (i.e., subrecipients); and
  - Key Participants (i.e., individuals who contribute in a substantive, measurable way to the execution of the proposed project);
- Technical Topic or Area; and
- Abstract – The abstract provided should be not more than 200 words in length, and should provide a truncated explanation of the proposed project.

D. Content and Form of the Concept Paper

Applicants must submit a Concept Paper for Topic Areas 1, 2, 3, 4a, and 4b. To be eligible to submit a Full Application, applicants for those topics areas 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:
Topic Areas 1, 2, 3, 4a, and 4b:

Section	Page Limit	Description
Cover Page Section	1 page maximum	The cover page should include the project title, the specific announcement 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.
Technology Description and Addendum	4 pages maximum	Technology Description -- 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, capabilities, and diversity of the proposed Project Team, including: • Whether the Principal Investigator (PI) and Project Team have the skill and expertise needed to successfully execute the project plan; • Whether the applicant has prior experience which demonstrates an ability to perform tasks of similar risk and complexity; • Whether the applicant has worked together with its teaming partners on prior projects or programs; • 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; and • Whether the applicant and the partners have successfully promoted the participation of under-represented groups in R&D activities. • Applicants may provide graphs, charts, or other data to supplement their Technology Description.
Concept Slide	1 page maximum	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 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 Full Application

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

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

All Full Application documents must be marked with the Control Number issued to the applicant. Applicants will receive a control number upon submission of their Letter of Intent in EERE Exchange, 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:

Topic Areas 1, 2, 3, 4a, and 4b:

Component	File Format	Page Limit	File Name
Technical Volume	PDF	15	ControlNumber_LeadOrganization_TechnicalVolume
Resumes	PDF	1	ControlNumber_LeadOrganization_Resumes
Letters of Commitment	PDF	1	ControlNumber_LeadOrganization_LOCs
SF-424	PDF		ControlNumber_LeadOrganization_424
Budget Justification Workbook	MS Excel		ControlNumber_LeadOrganization

			_Budget_Justification
Summary/Abstract for Public Release	PDF	1	ControlNumber_LeadOrganization_Summary
Summary Slide	MS Powerpoint	1	ControlNumber_LeadOrganization_Slide
Subrecipient Budget Justification	MS Excel		ControlNumber_LeadOrganization_Subrecipient_Budget_Justification
DOE Work Proposal for FFRDC, if applicable (see DOE O 412.1A, Attachment 3)	PDF		ControlNumber_LeadOrganization_WP
Authorization from cognizant Contracting Officer for FFRDC	PDF		ControlNumber_LeadOrganization_FFRDCAuth
SF-LLL Disclosure of Lobbying Activities for Prime Applicant and Subrecipients	PDF		ControlNumber_LeadOrganization_SF-LLL
Foreign Entities and Foreign Work	PDF		ControlNumber_LeadOrganization_Waiver
U.S. Manufacturing Plan	PDF		ControlNumber_LeadOrganization_USMP
Diversity and Inclusion Plan	PDF	2	ControlNumber_LeadOrganization_DIP

Topic Areas 5a and 5b:

Component	File Format	Page Limit	File Name
Technical Volume	PDF	5	ControlNumber_LeadOrganization_TechnicalVolume
SF-424	PDF		ControlNumber_LeadOrganization_424
Summary Slide for Public Release	MS Powerpoint	1	ControlNumber_LeadOrganization_Slide
SF-LLL Disclosure of Lobbying Activities for Prime Applicant and Subrecipients	PDF		ControlNumber_LeadOrganization_SF-LLL
Diversity and Inclusion Plan	PDF	2	ControlNumber_LeadOrganization_DIP

Please note the following documents will be required at such time the application is selected for award:

Component	File Format	Page Limit	File Name
Budget Justification Workbook	MS Excel		ControlNumber_LeadOrganization_Budget_Justification
Subrecipient Budget Justification	MS Excel		ControlNumber_LeadOrganization_Subrecipient_Budget_Justification

DOE Work Proposal for FFRDC, if applicable (see DOE O 412.1A, Attachment 3)	PDF		ControlNumber_LeadOrganization_WP
Authorization from cognizant Contracting Officer for FFRDC	PDF		ControlNumber_LeadOrganization_FFRDCAuth
Foreign Entities and Foreign Work	PDF		ControlNumber_LeadOrganization_Waiver
Data Management Plan	PDF		ControlNumber_LeadOrganization_DMP

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:

TechnicalVolume_Part_1
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 PDF format. The Technical Volume must conform to the following content and form requirements, including maximum page lengths. If applicants exceed the maximum page lengths indicated below, EERE will review only the authorized number of pages and disregard any additional pages. This volume must address the Merit Review Criteria as discussed in Section V.A.ii of the FOA. Save the Technical Volume in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_TechnicalVolume".

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

The Technical Volume to the Full Application may not be more than the number of pages specified in the table below, 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.

Topic Area Number	Topic Area Title	Page Limit
1	50-Year Service Life PV Systems (PV-50)	15
2	SOLAR R&R: Scalable Outputs for Leveraging Advanced Research on Receivers & Reactors	15
3	PTES: Pumped Thermal Energy Storage	15
4a	CSP PERFORM: Process Enhancement and Refinement For Operations, Reliability, and Maintenance	15
4b	CSP REFORM: Research in Equipment For Optimized and Reliable Machinery	15
5a	SIPS-PV	5
5b	SIPS-CSP	5

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:

Topic Areas 1, 2, 3, 4a, and 4b:

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 (Approximately 10% of the Technical Volume)	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.
Technical Description, Innovation, and Impact (Approximately 30% of the Technical Volume)	The Technical Description should contain the following information: • Relevance and Outcomes: The applicant should provide a detailed description of the technology, including the scientific and other principles and objectives 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 technical targets or other relevant performance targets. The applicant should clearly specify the expected outcomes of the project. • Feasibility: The applicant should demonstrate the technical feasibility of the proposed technology and capability of achieving the anticipated performance targets, including a description of previous work done and prior results. • Innovation and Impacts: The applicant should describe the current state-of-the-art in the applicable field, the specific innovation of the proposed technology, the advantages of proposed technology over current and emerging technologies, and the overall impact on advancing the state-of-the-art/technical baseline if the project is successful. The application should include a justification for the impact assessment approach and impact claim (e.g. performance improvement expectations and ramifications, cost model with references, future market opportunity size, etc.) as well as a description of the pathway to achieve stated impact after the end of the proposed project's period of performance.
Summary Statement of Project Objectives (Approximately 40% of	Provide a succinct description of the specific activities to be conducted over the proposed period of performance. Descriptions should contain enough detail to convey and disclose the work occurring. (Vague statements such

the Technical Volume)	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-M7), Estimated total task budget

Task Description: Task summaries shall explicitly identify:

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

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

	(Optional)Subtask description: Subtask descriptions: • Explicitly identify the task objectives/outcomes being addressed and a concise statement of the objectives of that subtask. • Describe the work and techniques that will be used and the expected result that will be generated from the effort. **(Optional) Subtask 1.2**: Distinctive title, Date range (M2-M7) (Continue until all Task 1 subtasks are listed) **Task 2:** (Continue in the format above until all tasks and subtasks are listed) o **Subtask 2.1:**
Technical Qualifications and Resources (Approximately 20% of the Technical Volume)	The Technical Qualifications and Resources should contain the following information: • Describe the project team's unique qualifications and expertise, including those of key subrecipients. • Describe the 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. • This section should also include relevant, previous work efforts, demonstrated innovations, and how these enable the applicant to achieve the project objectives. • Describe the time commitment of the key team members to support the project. • Describe the technical services to be provided by DOE/NNSA FFRDCs, if applicable. • For multi-organizational or multi-investigator projects, describe succinctly: o The roles and the work to be performed by each PI and Key Participant; o Business agreements between the applicant and each PI and Key Participant; o How the various efforts will be integrated and managed; o Process for making decisions on scientific/technical direction; o Publication arrangements; o Intellectual Property issues; and o Communication plans
Appendices	• Applicants should attach letters of commitment from all Subrecipient/third party cost share providers as an appendix. Letters of commitment do not count towards the page limit.

	• Applicants may attach one-page letters of support from other relevant entities (i.e. end users of the proposed solution) as an appendix. Letters of support do not count towards the page limit. Multi-page letters of support are not allowed and will not be reviewed. • Applicants may attach one or two-page resumes for key participating team members as an appendix. Resumes do not count towards the page limit. Resumes over 2 pages are not allowed and will not be reviewed. • Note: Footnotes and endnotes are counted toward the maximum page requirement. Applicants may not include a list of references as an appendix. References and outside links to additional content may be considered by reviewers, however, applications should not require references or outside content to be understood and reviewed.

Topic Areas 5a and 5b:

SIPS Application Technical Volume Section	Description

Cover Page
[1 Page Max]
	• Project Title
	• The specific FOA Topic Area being addressed and Project Focus Area(s): e.g., Photovoltaics, CdTe deposition, Reliability, 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, measurable way to the execution of the proposed project); and
	• Budget - Include a high-level overview of estimated total project budget
	• Any Statements regarding confidentiality
	• No additional information, such as an application abstract, should be included on this page

Project Description **[4 Pages Max]**	Applicants are required to describe succinctly: • The proposed technology or solution, including its basic operating principles and how it is unique and innovative; • The current state of the art in the relevant field and application, including key shortcomings, limitations, and challenges; • How the proposed project will overcome the shortcomings, limitations, and challenges in the relevant field and application; • The potential impact, with justification, that the proposed project

	would have on the relevant field and application and its relevance to industry and SETO goals as described in Section I.B. • Include a clear and concise (high-level) statement of the midpoint and end goals of the project. Each goal should be quantifiable and verifiable. • The most challenging risks the proposed project will likely face and mitigation strategies • The aspects of the team that are most relevant to the proposed work (i.e. applicant experience in the field and in working together, equipment and facilities access, etc.) • Applicants may provide graphs, charts, or other data to supplement their Technology Description, however, this supplemental information will count toward the page limit. • 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.
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)

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_424".

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 (DOE share and cost share), 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 slide summarizing the proposed project. This slide is used during the evaluation process.

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.

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

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-chg1-AdmChg 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-individual-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; or
- 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)

i. **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.

ii. **Performance of Work in the United States (Foreign Work Waiver)**
As set forth in Section IV.J.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

Topic Areas 1, 2, 3, 4a, and 4b:
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 U.S. Manufacturing Plan represents the applicant's measurable commitment to support U.S. manufacturing as a result of its award.

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

Due to the lower technology readiness levels of this FOA, DOE does not expect the U.S. Manufacturing Plans to be tied to a specific product or technology. However, 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.J. 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".

Topic Areas 5a and 5b:
EERE requires subject inventions (i.e., inventions conceived or first actually reduced to practice under EERE awards) to be substantially manufactured in the United States by project teams and their licensees, as described below. The applicant may request a modification or waiver of the U.S. manufacturing requirement.

1. **Domestic Small Businesses, Educational Institutions and Nonprofits**
   Domestic small businesses (including small business concerns), domestic educational institutions, and nonprofits that are recipients or subrecipients under EERE funding agreements must require their exclusive licensees to substantially manufacture the following products in the United States for any use or sale in the United States: (1) articles embodying subject inventions, and (2) articles produced through the use of subject inventions. This requirement does not apply to articles that are manufactured for use or sale overseas.

   Domestic small businesses, domestic educational institutions and nonprofits must require their assignees to apply the same U.S. manufacturing requirements to their exclusive licensees.

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

2. **Large Businesses, Foreign Entities, and State and Local Government Entities**
   Large businesses and foreign entities that are recipients or subrecipients under EERE funding agreements that take title to subject inventions through a patent waiver are required to substantially manufacture the following products in the United States: (1) products embodying subject inventions, and (2) products produced through the use of subject invention(s). This requirement applies to products that are manufactured for use or sale in the United States or overseas.

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

3. **FFRDCs**
   DOE FFRDCs are subject to the U.S. manufacturing requirements set forth in their M&O Contracts. All other FFRDCs are subject to the U.S. manufacturing requirements as set forth above, based on their size and for-profit status.

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.

Each Data Management Plan for this FOA must include the following elements:

1. A description of the data that will be generated during the course of the project, organized by dataset.
2. A description of the process to identify the dataset(s) and allowing indexing or cataloging.
3. A description of how data will be accessed (e.g. possible repositories, anonymous or registered access, etc.).
4. A list of methods to ensure data security or protection (if necessary) and data integrity (e.g. signed or hashed data).
5. A list of suitable standards and formats to be considered, including software code and tools that are necessary to use the dataset (open standards and well-documented formats are strongly recommended) and describe metadata that will accompany dataset.
6. A list of possible licenses to be applied to generated dataset(s) to allow use of the dataset(s) by others.
7. A description of the manner in which alignment with the DMP will be monitored and managed, including the review for potentially embedded PII and CII.
8. A description of the long-term management of the dataset beyond the expiration of the award or moratorium (a minimum of 10 years open access to the dataset is desirable.)
9. A description of how data sharing and preservation will enable validation of the results from the proposed work, including how the results could be validated if data are not shared or preserved.
10. Describe a plan for making all research data displayed in publications resulting from the proposed work digitally accessible at the time of publications. An applicant may select one of the two options below to satisfy this requirement regarding publications.

    Option 1: 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 five (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.

For datasets that will be created in the course of this project as part of the project's deliverables and whose utility extends beyond the confines of the project, i.e. it is useful for the community of researchers and industry stakeholders. The plan should comply with the FAIR guiding principles for data. That is, the dataset must be Findable by being indexed in well-known public catalogs and by having a unique Document Object Identifier (DOI); Accessible by being hosted in a suitable long-term repository; Interoperable by being accompanied by the necessary metadata and stored in well-known data formats; Reusable by permitting others to use the data based on a suitable Creative Commons License (e.g. CC0, CC-BY, CC-BY-SA).

If a dataset cannot be shared as generated according to the FAIR principles due to embedded Personally Identifiable Information, or Critical Infrastructure Information, the awardee should make a reasonable effort to scrub the dataset from the offending information or generate a functionally equivalent dataset that is unencumbered and can comply to FAIR principles.

Applicants under this FOA are strongly encouraged to license under a major Open Source License (e.g. GNU Public License, Library GNU Public License, MIT X License, BSD 3-Clause License, Apache Public Software License, etc.) any software code that is generated in the course of the project as part of the project's deliverables.

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

xiv. Diversity, Equity, and Inclusion Plan

It is important that the activities funded under this FOA do not overlook disadvantaged communities[94] and underrepresented groups. Accordingly, applicants must submit a Diversity and Inclusion Plan that outlines actions to create welcoming and inclusive environments to support people from underrepresented groups, and encourages the inclusion of individuals from these groups in the project's R&D activities. The plan should also contain SMART milestones supported by metrics to measure the success of the proposed actions.

A non-exhaustive list of actions that can serve as examples follow below:

- Include persons from underrepresented groups as PI, co-PI, and/or other senior personnel;
- Include persons from underrepresented groups as student researchers or post-doctoral researchers;
- Include faculty or students from minority-serving institutions as PI/co-PI, senior personnel, and/or student researchers, as applicable;
- Enhance or collaborate with existing diversity programs at your home organization and/or nearby organizations;
- Disseminate results of research and development in minority-serving institutions or other appropriate institutions serving disadvantaged communities;
- Implement evidence-based, diversity-focused education programs (such as implicit bias training for staff) in your organization;
- Identify businesses owned by underrepresented groups to solicit as vendors and sub-contractors for bids on supplies, services and equipment.

Save the Diversity and Inclusion Plan in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_DIP".

F. Content and Form of Replies to Reviewer Comments

If replies to reviewer comments are applicable (encouraged for Topic Areas 1, 2, 3, 4a, and 4b), EERE will provide applicants with reviewer comments following the

[94] DOE defines "disadvantaged communities" to be areas that most suffer from a combination of economic, health, and environmental burdens, such as, poverty, high unemployment, air and water pollution, presence of hazardous wastes as well as high incidence of asthma and heart disease. Examples include, but are not limited to: economically distressed communities identified by the Internal Revenue Service as Qualified Opportunity Zones; communities identified as disadvantaged communities by their respective States; communities identified on the Index of Deep Disadvantage referenced at https://news.umich.edu/new-index-ranks-americas-100-most-disadvantaged-communities/, and communities that otherwise meet the DOE definition of a disadvantaged community.

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

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

Replies to Reviewer Comments must conform to the following content and form requirements, including maximum page lengths, described below. If a Reply to Reviewer Comments is more than three (3) pages in length, EERE will review only the first three (3) pages and disregard any additional pages.

Topic Areas 1, 2, 3, 4a, and 4b:

SECTION	PAGE LIMIT	DESCRIPTION
Text	2 pages max	Applicants may respond to one or more reviewer comments or supplement their Full Application.
Optional	1 page max	Applicants may use this page however they wish; text, graphs, charts, or other data to respond to reviewer comments or supplement their Full Application are acceptable.

G. 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; and
- Environmental Questionnaire.

H. 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.
Submission Dates and Times

All required submissions 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.

I. Intergovernmental Review

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

J. 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; and
- 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 whether 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. The applicant does not have the right to appeal EERE's decision concerning a waiver request.

iv. Construction

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

v. Foreign Travel

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

vi. Equipment and Supplies

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

Property disposition will be required at the end of a project if the current fair market value of property exceeds $5,000. For-profit entity disposition requirements are set forth at 2 CFR 910.360. Property disposition requirements for other non-federal entities are set forth in 2 CFR 200.310 – 200.316.

vii. Domestic Preference – Infrastructure Projects

As appropriate and to the extent consistent with law, Applicants shall ensure that, to the greatest extent practicable, iron and aluminum as well as steel, cement, and other manufactured products (items and construction materials composed in whole or in part 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) used in the proposed project shall be produced in the United States. This requirement shall flow down to all sub-awards including all contracts, subcontracts and purchase orders for work performed under the proposed project.

viii. 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-individual-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; or
- An employee of a Member of Congress.

ix. 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

x. 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; and
- Other items as required by DOE.

V. Application Review Information

A. Technical Review Criteria

i. Concept Papers

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

Topic Areas 1, 2, 3, 4a, and 4b:

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

- 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; and
- The proposed work, if successfully accomplished, would clearly meet the objectives as stated in the FOA.

ii. Full Applications

Applications will be evaluated against the merit review criteria shown below.

Topic Areas 1, 2, 3, 4a, 4b, 5a and 5b:

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. If and as applicable, the project offers broad and open access to its major data and software code products.

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. The Diversity and Inclusion plan has adequate quality and extent to successfully broaden participation in and awareness of SETO-funded projects.

iii. Criteria for Replies to Reviewer Comments

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

B. Standards for Application Evaluation

Applications that are determined to be eligible will be evaluated in accordance with this FOA, by the standards set forth in EERE's Notice of Objective Merit Review Procedure (76 Fed. Reg. 17846, March 31, 2011) and the guidance provided in the "DOE Merit Review Guide for Financial Assistance," effective September 2020, 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:

Topic Areas 1, 2, 3, 4a, and 4b:

- 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;
- The degree to which the proposed project will accelerate transformational technological 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 exhibits technological or programmatic diversity when compared to the existing DOE project portfolio and other projects selected from the subject FOA;
- 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 project improves resilience of critical infrastructure;
- The degree to which the applicant team's drive, knowledge, and diverse experience provide a strong competitive edge and instill confidence that they will meet the objectives of this FOA.

Diversity (other than technological)

- The degree to which the proposed project exhibits team member diversity, with participants including but not limited to those from Minority Serving Institutions (MSIs) (e.g. Historically Black Colleges and Universities (HBCUs)/Other Minority Institutions (OMIs)),[95] Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, Veteran Owned Businesses, or members within disadvantaged communities; and
- The degree to which the proposed project, or group of projects, represent a desired geographic distribution (considering past awards and current applications).

Optimize Funding

- The degree to which the proposed project avoids duplication/overlap with other publicly or privately funded work.

Market Impact

- The degree to which the proposed project enables new and expanding market segments.

[95] Minority Serving Institutions (MSIs), including HBCUs/OMIs as educational entities recognized by the Office of Civil Rights (OCR), U.S. Department of Education, and identified on the OCR's Department of Education U.S. accredited postsecondary minorities' institution list. See https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html.

EE/Deployment

- The degree to which the project's solution or strategy will maximize deployment or replication.

Tech Transfer

- The degree to which the project promotes increased coordination with nongovernmental entities for demonstration of technologies and research applications to facilitate technology transfer.

Topic Areas 5a and 5b:

- The degree to which the proposed project exhibits technological 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;
- The degree to which the proposed project is likely to lead to increased employment and manufacturing in the United States;
- The degree to which the proposed project will accelerate transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty.

Diversity (other than technological)

- The degree to which the proposed project exhibits team member diversity, with participants including but not limited to those from Minority Serving Institutions (MSIs) (e.g. Historically Black Colleges and Universities (HBCUs)/Other Minority Institutions (OMIs)),[96] Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, Veteran Owned Businesses, or members within disadvantaged communities;
- The degree to which the proposed project collectively represents diverse types and sizes of applicant organizations; and
- The degree to which the proposed project, or group of projects, represent a desired geographic distribution (considering past awards and current applications).

[96] Minority Serving Institutions (MSIs), including HBCUs/OMIs as educational entities recognized by the Office of Civil Rights (OCR), U.S. Department of Education, and identified on the OCR's Department of Education U.S. accredited postsecondary minorities' institution list. See https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html.

D. Evaluation and Selection Process

i. Overview

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

ii. Pre-Selection Interviews

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

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

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

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

iii. Pre-Selection Clarification

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

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

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

iv. Recipient Integrity and Performance Matters

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

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

DOE will consider any written comments by the applicant, in addition to the other information in the designated integrity and performance system, in making a judgment about the applicant's integrity, business ethics, and record of performance under federal awards when completing the review of risk posed by applicants as described in 2 CFR 200.205.

v. Selection

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

E. Anticipated Notice of Selection and Award Negotiation Dates

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

VI. Award Administration Information

A. Award Notices

i. Ineligible Submissions

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

ii. Concept Paper Notifications

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

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

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

iii. Full Application Notifications

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

Full Applications will be made at a later date, subject to the availability of funds or other factors.

iv. Successful Applicants

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

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

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

v. Alternate Selection Determinations

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

vi. Unsuccessful Applicants

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

B. Administrative and National Policy Requirements

i. Registration Requirements

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

1. **EERE Exchange**
   Register and create an account on EERE Exchange at https://eere-Exchange.energy.gov. This account will then allow the user to register for any open EERE FOAs that are currently in EERE Exchange. It is recommended that each organization or business unit, whether acting as a team or a single entity, use only one account as the contact point for each submission. Applicants should also designate backup points of contact so they may be easily contacted if deemed necessary. **This step is required to apply to this FOA.** The EERE Exchange registration does not have a delay; however, **the remaining registration requirements below could take several weeks to process and are necessary for a potential applicant to receive an award under this FOA.**

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

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

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

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

6. **Electronic Authorization of Applications and Award Documents**

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

ii. Award Administrative Requirements

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

iii. Foreign National Access

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.

iv. Subaward and Executive Reporting

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

v. National Policy Requirements

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

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

EERE's decision whether and how to distribute federal funds under this FOA is subject to NEPA (42 U.S.C. 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 https://www.energy.gov/nepa.

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.

vii. Applicant Representations and Certifications

1. Lobbying Restrictions

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

2. Corporate Felony Conviction and Federal Tax Liability Representations

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

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

b. It is **not** a corporation that has any unpaid federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

For purposes of these representations the following definitions apply:

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

3. Nondisclosure and Confidentiality Agreements Representations

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

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

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

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

(2) The limitation above shall not contravene requirements applicable to Standard Form 312 Classified Information Nondisclosure Agreement (https://fas.org/sgp/othergov/sf312.pdf), Form 4414 Sensitive Compartmented Information Disclosure Agreement (https://fas.org/sgp/othergov/intel/sf4414.pdf), or any other form issued by a federal department or agency governing the nondisclosure of classified information.

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

viii. Statement of Federal Stewardship

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

ix. Statement of Substantial Involvement

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

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

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

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

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

x. Subject Invention Utilization Reporting

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

xi. Intellectual Property Provisions

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

xii. Reporting

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

xiii. Go/No-Go Review

Each project selected under this FOA will be subject to a periodic project evaluation referred to as a Go/No-Go Review. At the Go/No-Go decision points, EERE will evaluate project performance, project schedule adherence, meeting milestone objectives, compliance with reporting requirements, and overall contribution to the EERE program goals and objectives. Federal funding beyond the Go/No-Go decision point (continuation funding) is contingent upon (1) availability of federal funds appropriated by Congress for the purpose of this program; (2) the availability of future-year budget authority; (3) recipient’s technical progress compared to the Milestone Summary Table stated in Attachment 1 of the award; (4) recipient’s submittal of required reports; (5) recipient’s compliance with the terms and conditions of the award; (6) EERE’s Go/No-Go decision; (7) the recipient’s submission of a continuation application; and (8) written approval of the continuation application by the Contracting Officer.

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

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

xiv. Conference Spending

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

xv. Uniform Commercial Code (UCC) Financing Statements

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

Properly record, and consent to the Department's ability to properly record if the recipient fails to do so, UCC financing statement(s) for all equipment in excess of $5,000 purchased with project funds. These financing statement(s) must be approved in writing by the Contracting Officer prior to the recording, and they shall provide notice that the recipient's title to all equipment (not real property) purchased with federal funds under the financial assistance agreement is conditional pursuant to the terms of this section, and that the government retains an undivided reversionary interest in the equipment. The UCC financing statement(s) must be filed before the Contracting Officer may reimburse the recipient for the federal share of the equipment unless otherwise provided for in the relevant financial assistance agreement. The recipient shall further make any amendments to the financing statements or additional recordings, including appropriate continuation statements, as necessary or as the Contracting Officer may direct.

xvi. Implementation of Executive Order 13798, Promoting Free Speech and Religious Liberty

States, local governments, or other public entities may not condition sub-awards in a manner that would discriminate, or disadvantage sub-recipients based on their religious character.

xvii. Table of Personnel

If selected for award negotiations, the selected applicant must submit a list of personnel who are proposed to work on the project, both at the recipient and subrecipient level. The table should include the individuals' names, job titles, role in the project and their organization. Recipients will have an ongoing responsibility to notify DOE of changes to the personnel and submit an updated list during the life of the life of the award as there are changes to the personnel working on the project.

xviii. Pending and Current Sources of Support

Current and Pending support is intended to allow the identification of potential duplication, overcommitment, potential conflicts of interest or commitment, and all other sources of support. If selected for award negotiations, the principal investigator and each senior/key person at the recipient and subrecipient level must provide a list of all sponsored activities, awards, and appointments, whether paid or unpaid; provided as a gift with terms or conditions or provided as a gift without terms or conditions; full-time, part-time, or voluntary; faculty, visiting, adjunct, or honorary; cash or in-kind; foreign or domestic; governmental or private-sector; directly supporting the individual's research or indirectly supporting the individual by supporting students, research staff, space, equipment, or other research expenses. All foreign government-sponsored talent recruitment programs must be identified in current and pending support. The information may be provided in the format approved by the National Science Foundation (NSF), which may be generated by the Science Experts Network Curriculum Vita (SciENcv), a cooperative venture maintained at https://www.ncbi.nlm.nih.gov/sciencv/, and is also available at https://www.nsf.gov/bfa/dias/policy/nsfapprovedformats/cps.pdf. The use of a format required by another agency is intended to reduce the administrative burden to researchers by promoting the use of common formats.

For every activity, list the following items:

- The sponsor of the activity or the source of funding;
- The award or other identifying number;
- The title of the award or activity. If the title of the award or activity is not descriptive, add a brief description of the research being performed that would identify any overlaps or synergies with the proposed research;
- The total cost or value of the award or activity, including direct and indirect costs and cost share. For pending proposals, provide the total amount of requested funding;
- The award period (start date – end date);
- The person-months of effort per year being dedicated to the award or activity;

- If required to identify overlap, duplication of effort, or synergistic efforts, append a description of the other award or activity to the current and pending support; and
- Details of any obligations, contractual or otherwise, to any program, entity, or organization sponsored by a foreign government must be provided on request to either the applicant institution or DOE.

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: *PV.CSP.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.

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

The cover sheet of the Full Application, and 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 Reviews and Peer Reviews, 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 Full Applications 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 for Domestic Large Businesses: DOE has issued a class patent waiver that applies to this FOA. Under this class patent 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 patent 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: For applicants that don't fall under the class patent waiver or the Bayh-Dole Act, those 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 time frames 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.

- DEC: Each applicant is required to submit a U.S. Manufacturing Plan as part of its application. 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.

i. 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.

ii. 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.

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 (DOE share) 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 CFR 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 (DOE share) 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 CFR 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 the cover page of the FOA.

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 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.

(a) Under Federal research proposals, voluntary committed cost sharing is not expected. It cannot be used as a factor during the merit review of applications or proposals, but may be considered if it is both in accordance with Federal awarding agency regulations and specified in a notice of funding opportunity. Criteria for considering voluntary committed cost sharing and any other program policy factors that may be used to determine who may receive a Federal award must be explicitly described in the notice of funding opportunity. See also §§200.414 Indirect (F&A) costs, 200.203 Notices of funding opportunities, and Appendix I to Part 200—Full Text of Notice of Funding Opportunity.

(b) For all Federal awards, any shared costs or matching funds and all contributions, including cash and third party in-kind contributions, must be accepted as part of the non-Federal entity's cost sharing or matching when such contributions meet all of the following criteria:

(1) Are verifiable from the non-Federal entity's records;

(2) Are not included as contributions for any other Federal award;

(3) Are necessary and reasonable for accomplishment of project or program objectives;

(4) Are allowable under Subpart E—Cost Principles of this part;

(5) Are not paid by the Federal Government under another Federal award, except where the Federal statute authorizing a program specifically provides that Federal funds made available for such program can be applied to matching or cost sharing requirements of other Federal programs;

(6) Are provided for in the approved budget when required by the Federal awarding agency; and

(7) Conform to other provisions of this part, as applicable.

(c) Unrecovered indirect costs, including indirect costs on cost sharing or matching may be included as part of cost sharing or matching only with the prior approval of the Federal awarding agency. Unrecovered indirect cost means the difference between the amount charged to the Federal award and the amount which could have been charged to the Federal award under the non-Federal entity's approved negotiated indirect cost rate.

(d) Values for non-Federal entity contributions of services and property must be established in accordance with the cost principles in Subpart E—Cost Principles. If a Federal awarding agency authorizes the non-Federal entity to donate buildings or land for construction/facilities acquisition projects or long-term use, the value of the donated property for cost sharing or matching must be the lesser of paragraphs (d)(1) or (2) of this section.

(1) The value of the remaining life of the property recorded in the non-Federal entity's accounting records at the time of donation.

(2) The current fair market value. However, when there is sufficient justification, the Federal awarding agency may approve the use of the current fair market value of the donated property, even if it exceeds the value described in (1) above at the time of donation.

(e) Volunteer services furnished by third-party 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 third-party volunteer services must be consistent with those paid for similar work by the non-Federal entity. In those instances in which the required skills are not found in the non-Federal entity, rates must be consistent with those paid for similar work in the labor market in which the non-Federal entity competes for the kind of services involved. In either case, paid fringe benefits that are reasonable, necessary, allocable, and otherwise allowable may be included in the valuation.

(f) When a third-party organization furnishes the services of an employee, these services must be valued at the employee's regular rate of pay plus an amount of fringe benefits that is reasonable, necessary, allocable, and otherwise allowable, and indirect costs at either the third-party organization's approved federally negotiated indirect cost rate or, a rate in accordance with §200.414 Indirect (F&A) costs, paragraph (d), provided these services employ the same skill(s) for which the employee is normally paid. Where donated services are treated as indirect costs, indirect cost rates will separate the value of the donated services so that reimbursement for the donated services will not be made.

(g) Donated property from third parties may include such items as equipment, office supplies, laboratory supplies, or workshop and classroom supplies. Value assessed to donated property included in the cost sharing or matching share must not exceed the fair market value of the property at the time of the donation.

(h) The method used for determining cost sharing or matching for third-party-donated equipment, buildings and land for which title passes to the non-Federal entity may differ according to the purpose of the Federal award, if paragraph (h)(1) or (2) of this section applies.

(1) If the purpose of the Federal award is to assist the non-Federal entity in the acquisition of equipment, buildings or land, the aggregate value of the donated property may be claimed as cost sharing or matching.

(2) If the purpose of the Federal award is to support activities that require the use of equipment, buildings or land, normally only depreciation charges for equipment and buildings may be made. However, the fair market value of equipment or other capital assets and fair rental charges for land may be allowed, provided that the Federal awarding agency has approved the charges. See also §200.420 Considerations for selected items of cost.

(i) The value of donated property must be determined in accordance with the usual accounting policies of the non-Federal entity, with the following qualifications:

(1) The value of donated land and buildings must not exceed its fair market value at the time of donation to the non-Federal entity as established by an independent appraiser (e.g., certified real property appraiser or General Services Administration representative) and certified by a responsible official of the non-Federal entity as required by the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, as amended, (42 U.S.C. 4601-4655) (Uniform Act) except as provided in the implementing regulations at 49 CFR part 24.

(2) The value of donated equipment must not exceed the fair market value of equipment of the same age and condition at the time of donation.

(3) 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.

(4) The value of loaned equipment must not exceed its fair rental value.

(j) For third-party in-kind contributions, the fair market value of goods and services must be documented and to the extent feasible supported by the same methods used internally by the non-Federal entity.

(k) For IHEs, see also OMB memorandum M-01-06, dated January 5, 2001, Clarification of OMB A-21 Treatment of Voluntary Uncommitted Cost Sharing and Tuition Remission Costs.

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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 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.J.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

Insert other acronyms applicable to this FOA (e.g., technology office name, technical terms or metrics)

COI	Conflict of Interest
DEC	Determination of Exceptional Circumstances
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
M&O	Management and Operating
MPIN	Marketing Partner ID 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
R&D	Research and Development
RFI	Request for Information
RFP	Request for Proposal
SAM	System for Award Management
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