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

Concentrating Solar-Thermal Power Fiscal Year 2022 Research, Development, and Demonstration Program

Funding Opportunity Announcement (FOA) Number: [DE-FOA-0002630]

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FOA Issue Date:	02/08/2022
Informational Webinar:	02/24/2022
Submission Deadline for Concept Papers:	03/16/2022 5pm ET
Submission Deadline for Full Applications:	05/16/2022 5pm ET
Expected Submission Deadline for Replies to Reviewer Comments:	07/11/2022 5pm ET
Expected Date for EERE Selection Notifications:	09/09/2022
Expected Timeframe for Award Negotiations:	Sept 2022 – Nov 2022

- Applicants must submit a Letter of Intent and a Concept Paper by 5:00pm 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.

Modifications

All modifications to the FOA are highlighted in the body of the FOA. Changes from modification 000001 are highlighted in yellow. Changes from modification 000002 are highlighted in green.

Mod. No.	Date	Description of Modification
000001	2/8/2022	Update Teaming Partner List Link
000002	6/28/2022	Modified Replies to Reviewer Comments due date

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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, development, and demonstration (RD&D) that accelerates the large-scale development and deployment of solar technology to support an equitable transition to a decarbonized electricity system by 2035 and decarbonized energy sector by 2050. Achieving this goal 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.

SETO 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. In May 2021, SETO released its Multi-Year Program Plan[1], which describes the activities and specific goals for 2025. In September 2021, DOE released the Solar Futures Study,[2] which examined solar's role in achieving the decarbonization of the grid by 2035 and 2050. Both of these documents guide SETO's strategic efforts.

Building a clean and equitable energy economy and addressing the climate crisis is a top priority of the Biden Administration. This FOA will advance the Biden Administration's goals to achieve carbon pollution-free electricity by 2035 and to "deliver an equitable, clean energy future, and put the United States on a path to achieve net-zero emissions, economy-wide, by no later than 2050"[3] to the benefit of all Americans. The RD&D activities to be funded under this FOA will support the government-wide approach to the climate crisis by driving the innovation that can lead to the deployment of clean energy technologies, which are critical for climate protection.

Solar energy technologies are essential to achieving a 100% clean electricity system by 2035 and a net-zero energy system by 2050. According to the Solar Futures Study,[2] solar capacity will need to grow from 3% of the U.S. electricity supply today to 40% by 2035 and 45% by 2050. This will require the U.S. to install 30 GW_{ac} of solar power each year between now and 2025 and ramp up to 60 GW_{ac} per year from 2025-2030. With supportive policies, electrification, and aggressive cost reductions, solar energy could provide 1 terawatt (TW) of solar electricity to the grid by 2035 and 1.6 TW of electricity by 2050. Preliminary modeling

[1] SETO. SETO Multi-Year Program Plan. https://www.energy.gov/eere/solar/articles/solar-energy-technologies-office-multi-year-program-plan
[2] SETO. Solar Futures Study. https://www.energy.gov/eere/solar/solar-futures-study
[3] Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," January 27, 2021.

shows that decarbonizing the entire energy system could result in as much as 3 TW of solar capacity due to increased electrification across the energy system.

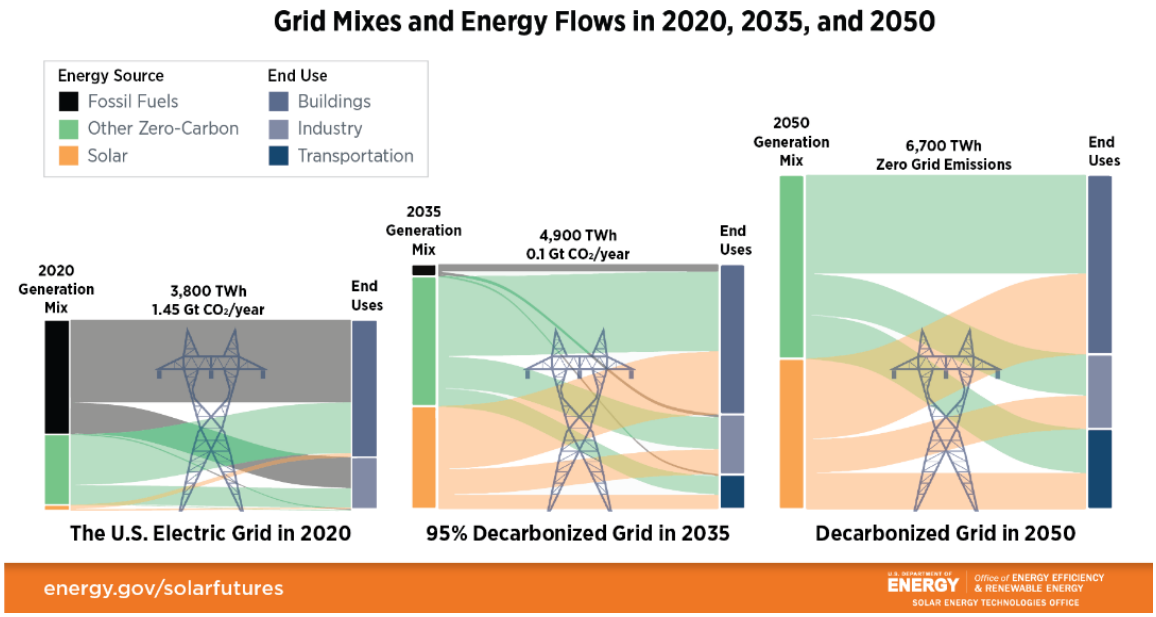

Figure 1: Solar capacity grows from 4% of the electricity mix today to 45% in 2050, serving more building, industry and transportation end uses. SOURCE: NREL/DOE Solar Futures Study

Achieving a decarbonized energy sector by 2050 will require the development of cost-effective technologies beyond today's commercial technologies. Increased deployment of solar technology, in particular, will require the deployment of flexible and dispatchable generation and energy storage technologies, like CSP with thermal energy storage, to ensure reliability of the grid.[4] Beyond the grid, renewable fuels and thermal technologies will help address applications that are difficult to decarbonize through elecitrification. This FOA will help decarbonize the energy system by developing CSP technologies for higher efficiency power cycles, increased flexibility and reliability through thermal storage, and carbon-free industrial processes in the United States. In addition, SETO has several prize competitions underway that support American leadership in the clean energy economy.[5] In sum, SETO's support of innovative RD&D will accelerate solar technology deployment and lower the costs to decarbonize our electricity grid.

Achieving this transition requires that the industry achieve SETO's 2030 cost targets, which would halve the cost of solar power from 2020-2030. In many parts of the country, solar electricity is already the lowest-cost form of new electricity generation capacity, but solar electricity is not yet cost-effective everywhere. There are multiple pathways to achieve these goals, but all require sustained innovation across solar energy technologies.

[4] Augustine, Chad, Craig Turchi, and Mark Mehos. 2021. *The Role of Concentrating SolarThermal Technologies in a Decarbonized U.S. Grid*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5700-80574. https://www.nrel.gov/docs/fy21osti/80574.pdf.

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

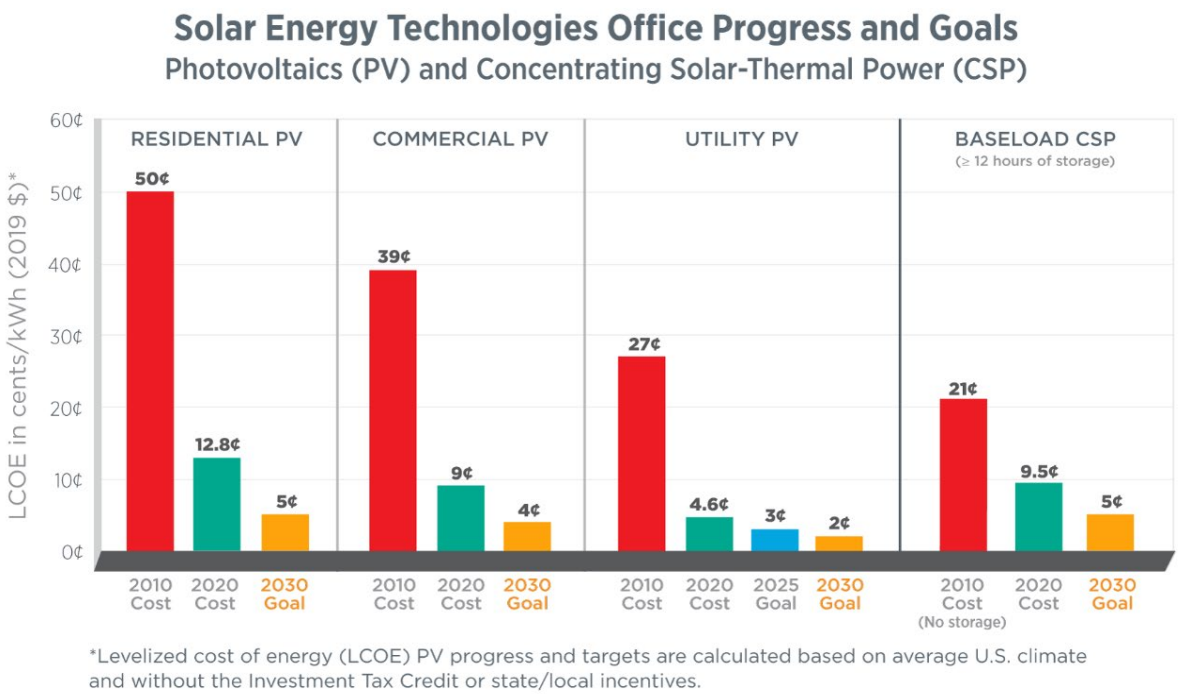

Figure 2: Cost of energy for PV and CSP technologies

While PV has dominated the U.S. solar market, with over 90 GW deployed by the end of 2020, CSP technologies offer a unique value as a renewable energy resource that can readily deliver high-temperature heat and inherently incorporates storage for on-demand solar energy. 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 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.[6]

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. Energy-dense thermochemical storage, potentially including production of synthetic fuels, may even be able to address 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.

[6] 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.

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. Solar energy can address this with the CSP technology. CSP directly produces high-temperature steam or other fluids, which is typically delivered to electricity-producing turbines. However, this solar-generated heat can also be directly integrated with thermally driven industrial processes like iron ore reduction and steel manufacture, cement production, and ammonia synthesis. 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.

The solar industry, which includes the research communities, does not match the diversity of the United States demographics.[7] Women and 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 RD&D activities in universities, National Laboratories, and private industry, the lack of diversity in that pipeline adversely affects the opportunities and potential scientific and economic outcomes.

ii. Technology Space and Strategic Goals

American innovation and technology development have played a key role in the development of CSP technologies, from the first commercial parabolic trough plants – the SEGS plants, built in the 1980s and 1990s – to the Solar One and Two demonstration plants. In particular, Solar Two,[8] directly supported by SETO, became the basis for today's molten nitrate salt-based CSP tower architecture, the current state-of-the-art for CSP and TES.

For next-generation CSP plants, SETO has set a target to lower the cost of electricity from baseload plants, with greater than 12 hours of storage, to $0.05/kWh by 2030. This represents, approximately, a 50% reduction of existing costs. Although this target is aggressive, there are multiple pathways to achieve it.[9] All pathways require significant improvements across SETO'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 3*, below, describes one potential pathway to $0.05/kWh by 2030.

[7] SEIA: U.S. Solar Industry Diversity Study 2019.
[8] Pacheco, et al. Final Test and Evaluation Results from the Solar Two Project. SAND2002-0120. https://www.osti.gov/biblio/793226
[9] SETO. 2030 Solar Cost Targets. https://www.energy.gov/eere/solar/articles/2030-solar-cost-targets

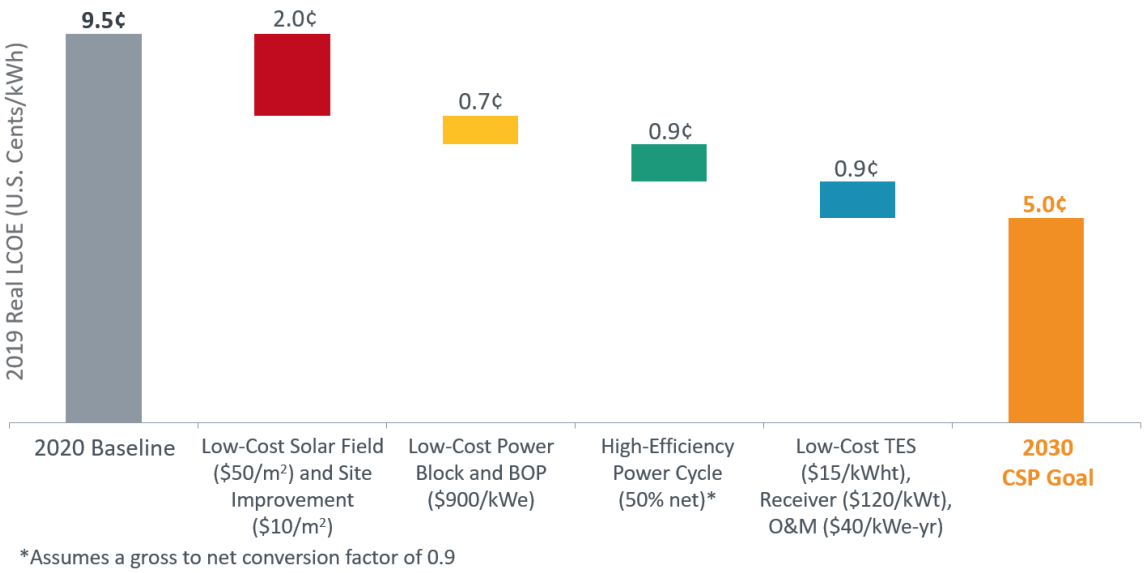

Figure 3: One scenario for reaching the $0.05/kwh LCOE goal from the 2018 benchmark[10]

The primary technical strategy being pursued to achieve this goal is to raise the temperature of the heat that next-generation CSP plants deliver to the power cycle, thereby increasing plant efficiency. The Generation 3 Concentrating Solar Power Systems[11] (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). These projects explored three different heat transfer pathways to 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. In March of 2021, SETO announced the selection of the pathway based on solid particle heat transfer media, led by Sandia National Laboratories, to receive approximately $25 million to build a megawatt-scale integrated test facility to validate the performance of this system.

Beyond CSP for electricity, SETO works to make solar industrial process heat (SIPH) a cost-effective alternative to conventional fuels. 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. Candidate applications for SIPH includes both 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.

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

In 2021, DOE launched the Long Duration Storage Energy EarthShot[12] to accelerate the development of energy storage technologies that store and deliver 10 or more hours of energy. The initiative aims to reduce the cost of these technologies by 90%, to a levelized cost of storage (LCOS) of $0.05/kWh$_e$ by the end of this decade. TES technologies are a particularly promising approach to long duration energy storage, due to the ability to scale storage duration independently of the power block. Increasing the duration of TES typically only requires larger volumes of low-cost storage media. This leads to significantly lower costs of additional storage, as compared to conventional battery technology. This FOA intends to support the development of TES technologies to support the goals of this EarthShot initiative.

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, SETO 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 SETO 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[13] 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.[14]

[12] https://www.energy.gov/eere/long-duration-storage-shot

[13] The term "equity" means the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality.

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

As part of this whole of government approach, this FOA seeks to encourage the participation of underserved communities[15] and underrepresented groups. Applicants are highly encouraged to include individuals from groups historically underrepresented[16,17] in STEM on their project teams. As part of the application, 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 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 underserved communities (See Section IV.D.i). The plan should include SMART (Specific, Measurable, Assignable, Realistic and Time-Related) milestones supported by metrics to measure the success of the proposed actions. This plan will be evaluated as part of the technical review process.

Further, Minority Serving Institutions[18], Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, Veteran Owned Businesses, or entities located in an underserved community that meet the eligibility requirements (See Section III) are encouraged to apply as the prime applicant or participate on an application as a proposed

[15] The term "underserved communities" refers to populations sharing a particular characteristic, as well as geographic communities, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life, as exemplified by the list of in the definition of "equity." E.O. 13985. For purposes of this FOA, as applicable to geographic communities, applicants can refer to economically distressed communities identified by the Internal Revenue Service as Qualified Opportunity Zones; communities identified as disadvantaged or underserved 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 definition of "underserved communities" stated above.

[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 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 inspire underrepresented Americans to pursue careers in energy and support their advancement into leadership positions. https://www.energy.gov/articles/introducing-minorities-energy-initiative

[17] See also. Note that Congress 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.

[18] Minority Serving Institutions (MSIs), including Historically Black Colleges and Universities/Other Minority Institutions) 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.

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.).

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 CSP technologies and creating new market opportunities for the industry, with the goal of enabling substantial deployment of CSP to decarbonize the electricity grid and energy system. These projects will work to make CSP applicable to new industries and advance the development of components for next-generation CSP systems based on solid particle heat transfer media.

One of the goals of publicly funded applied RD&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 RD&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 RD&D work, SETO supports commercialization efforts for the diffusion of the technologies, intellectual property, and expertise developed by the funded projects.

With this FOA, SETO intends to fund ambitious, high-impact research in two main topic areas: 1) Concentrating Solar Thermal for Industrial Decarbonization and 2) Concentrating Solar-thermal Particle Technologies for Generation 3 CSP and beyond (Gen3 ++).

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 an underserved community are 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

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

[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.

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://energy.gov/eere/solar/articles/funding-notice-concentrating-solar-thermal-power-fiscal-year-2022-research 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

The development of new thermal system technologies is inherently complicated by the typically non-linear correlation between component size and performance. Because large, commercial-scale systems generally have fundamental attributes (e.g. volumes, flow rates, etc.) orders of magnitudes larger than those achievable in the typical laboratory, it is intrinsically challenging to validate the performance of these systems with lab-scale prototypes. Mimicking the behavior of integrated components in a system is also challenging at the bench scale, which may impact the expected performance conditions of the component being developed. Commercial CSP power plants use thermal components at the 100-500 MW_{th} scale, can store more than 1,000 MWh of heat, and operate under daily temperature cycles from ambient to over 700 °C, for Gen3 systems. By comparison, bench-scale prototypes are typically built at sizes between 0.001-0.1 MW_{th}, and laboratory conditions can often only approximate expected environmental conditions.

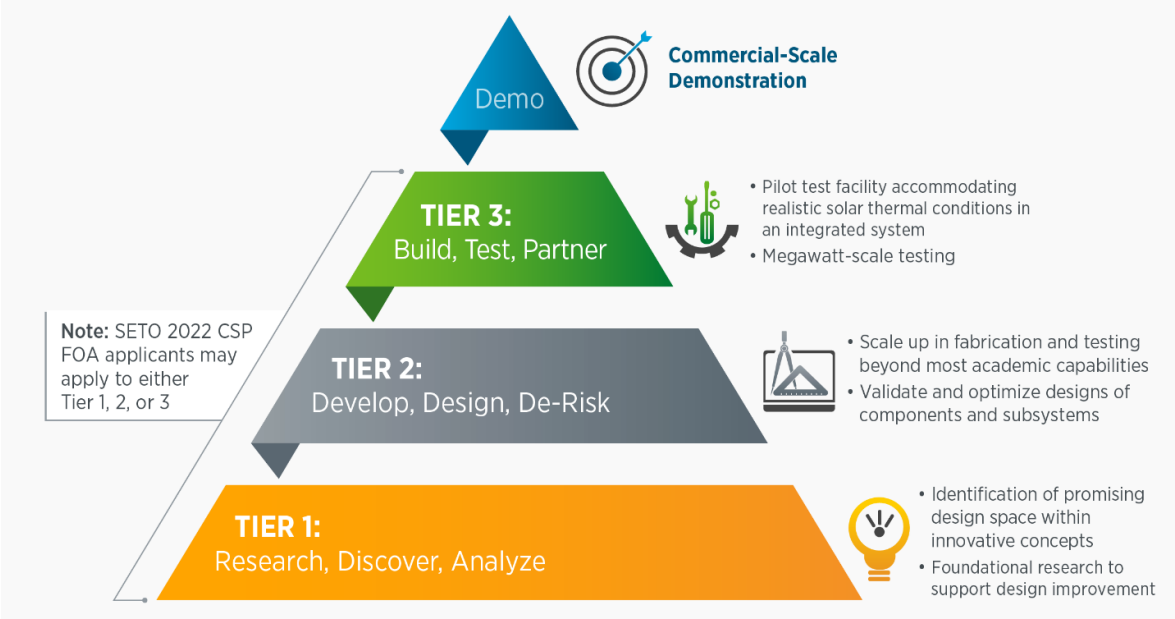

Figure 4: SOLAR Tier Structure

Additionally, bench scale experiments often use processes, parts, or designs that may be unsuitable for commercial systems. While this is often done intentionally to minimize external variables outside the scope of specific research project, this is sometimes caused by the absence of project partners and stakeholders with appropriate knowledge of industrial best practices. Early involvement of relevant partners can accelerate technology development by inspiring confidence in components and systems at smaller scales while significant iteration is still feasible. Large-scale thermal system projects require significant capital investment, and a trial-and-error testing approach at moderate and commercial sizes is not tenable.

With these challenges in mind, the topics in this FOA require applicants to respond within the framework of a rubric nicknamed SOLAR (Scalable Outputs for Leveraging Advanced Research). This SOLAR Tier structure (Figure 4) attempts to simultaneously address the risks of scale and to generate sufficient knowledge to maximize the value of large-scale demonstrations. Technology developers are required to look beyond near-term experimental goals and anticipate the practical challenges of subsequent development campaigns. Teams, technologies, and integration and commercialization strategies are expected to evolve as a concept advances from one tier to the next.

In both Topics of this FOA, applicants must explicitly indicate which of the SOLAR Tiers their proposal addresses. This section describes what is expected of proposals at each Tier. Within each topic, additional detail is provided specific to proposals in that area. In general, applicants should clearly communicate a vision for progressing a technology through each remaining Tier, ultimately building towards a commercial-scale demonstration. Pending appropriations and budget availability, SETO intends to run future solicitations to allow successful project teams to apply for funding to subsequent Tiers.

The SOLAR framework describes 3 Tiers for the development of components and systems. Projects should explicitly align with one of the following:

- Tier 1: Research, Discover, and Analyze
- Tier 2: Develop, Design, and De-Risk
- Tier 3: Build, Test, and Partner

At each Tier, it is important that key outputs are appropriately planned to enable the next stage of development for a novel technology. The ultimate goal of the SOLAR framework is to de-risk technologies sufficiently to enable large-scale system demonstrations while simultaneously developing a detailed understanding of material and system properties, cost, manufacturability, operability, and other technical features necessary to fully consider the benefits of the innovative system. Projects will be required to generate appropriate foundational knowledge for their technical maturity, demonstrated risk reduction, and forward-looking scalable designs. As project deliverables, these outputs must meet certain content and quality requirements, as detailed in each topic section.

Tiers and Stage-Gates

Tier 1. Research, Discover, Analyze

Applicants to Tier 1 should seek to prove – or disprove – that an innovation has adequate merit and value 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, typically at the 1-100 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 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. 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 the appropriate discovery space to give confidence that either leading candidates for critical aspects of the systems have been identified, or that no such candidate exists. Convincingly disproving a concept, or clarification and quantification of the key technology barriers, is considered a meritorious outcome, as 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.

Most Tier 1 projects should focus on broadly de-risking a specific technology. However, projects in Tier 1 may also address foundational research topics, directed at gaining a broader understanding of specific physical characteristics of materials or systems. Proposals

that address this kind of foundational data collection or analysis must provide a compelling argument as to how their proposed work will be broadly applicable to a range of component concepts, based on a state-of-the-art understanding of the literature and existing research efforts. Applicants should also clearly justify the value proposition of proposed work relative to existing knowledge, in terms of improved performance, increased reliability, lower cost, or other quantitative metrics. Research topics may include, but are not limited to:

- Material characterization, including investigations of difficult-to-measure thermophysical properties
- Durability and accelerated lifetime testing of materials (addressing both chemical and mechanical degradation mechanisms, as appropriate)
- Integrated system design and techno-economic analyses of novel CSP systems, including annualized performance and energy balance through a range of operational modes
- Heat transfer characterization of novel heat transfer or thermal storage media
- Evaluation of test plans, performance validation or analysis of resulting data
- Analytical methodologies or computational tools to assess a broad range of existing and new technologies
- Development of novel materials systems along with joining strategies and methods
- New metrology and measurement technologies with potential paths for system integration in service condition

Tier 2. Develop, Design, De-Risk

Tier 2 applications should propose a testing campaign sufficient to prove that the novel proposed concept is adequately understood to have a reasonable chance of commercial adoption once demonstrated under realistic conditions. This will likely include:

- High-fidelity lifetime testing
- A mature engineering analysis of the concept, including initial analysis of ancillary components and connection points
- Testing showing successful performance of integrated components
- 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 MW pilot
- A nominal design of a commercial-scale concept.

In this Tier, the team should have significant engagement with industry stakeholders to inform both the value proposition of the technology and the credibility of system cost and feasibility. Uncertainties around component pricing, operational strategies, and system integration should be substantially less than in Tier 1, based on multiple quotes, or, wherever possible, engagement with multiple stakeholders. Furthermore, significant engagement with a candidate Tier 3 test facility should begin to ensure feasibility of successful testing of a > 1 MW pilot. Capstone testing in Tier 2 should include a prototype on

the 100-500 kW scale, which attempts to match the boundary conditions of a real system concept.

Tier 3. Build, Test, Partner

Tier 3 projects will encompass procurement, construction or installation, commissioning, and testing at an identified test facility for a pilot-scale system. Research teams are expected to execute a testing campaign that fully exercises a component or system in a relevant environment, validates modeled performance under all potential operational modes, and ultimately minimizes risk in transitioning this idea to a commercial demonstration plant. Tier 3 projects should be designed to enable further investment and development by the private sector. Appropriate commercialization partners or other stakeholders should be involved in the project. Tier 3 projects are generally expected to be tested at a scale of at least 1 MW_{th} for at least 100 to 250 hours, although other metrics of scale may be appropriate, depending on the specific technology. The sophistication of a Tier 3 project will be judged, in part, by testing the operability of relevant components working in tandem rather than isolation. Tier 3 projects should have a well-developed concept for the commercial embodiment of the system.

Progressing between Tiers

If successful, applicants to Tier 1 or 2 should explicitly plan to graduate their project to Tier 2 and/or Tier 3 in future, analogous solicitations. Subject to Congressional appropriations and strategic priorities, SETO intends to periodically release FOAs with this or similar topics to support the multi-scale development of CSP-relevant technologies. Successful Tier 1 or 2 projects will need to apply to future solicitations to advance work to Tier 2 and/or 3.

The next section describes the topic areas to which the applicants should respond within the SOLAR Tier framework.

At DOE staff's discretion, applications may be reassigned from one Tier to another based on staff's assessment of technology maturity described in the application.

i. Topic Area 1: Concentrating Solar Thermal for Industrial Decarbonization

Introduction

Achieving a net-zero carbon economy by 2050 will require the adoption of clean energy technologies in sectors beyond electricity generation. Technologies that can eliminate the need to burn fossil fuels for heat-driven processes that produce essential commodities, refined products, and other goods are needed. The industrial sector is responsible for 28% of the nation's CO_2 emissions[21] [22]. Industrial processes that rely on electricity will reduce emissions as the electric sector decarbonizes, but only 12% of industrial energy

[21] Data source: EIA 2020, United States Energy Information Administration, Annual Energy Outlook 2020 with Projections to 2050. https://www.eia.gov/outlooks/aeo/

[22] EPA Greenhouse Gas Emissions: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#industry.

consumption is in the form of electricity[23]. Even with increasing renewable electricity availability, many industrial processes will be difficult to electrify because they require high temperatures or have other unique process characteristics.

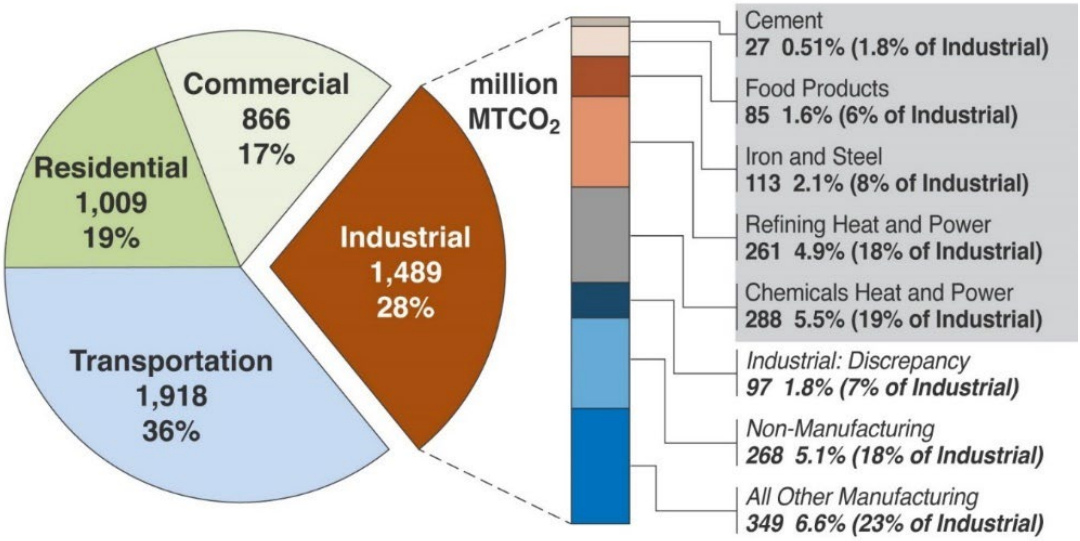

Figure 5: CO_2 emissions by industry. Source: DOE Advanced Manufacturing Office

Concentrating solar-thermal (CST) 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 deployment of integrated solar-thermal processes that can address the variability inherent in using sunlight as an energy source.

The focus of this topic is to enable CST with thermal energy storage (TES) to be integrated with high-temperature process technologies to produce economically important products, like steel, cement, ammonia, fuels, and other chemicals and fuels. These products are responsible for approximately half of all emissions from the industrial sector. Manufacturing processes are varied but all currently use fossil fuels as the primary heat source. All of these processes are primarily thermally driven chemical transformations, a significant percentage of which either use hydrogen as a key intermediate or can be readily redesigned to use hydrogen – whether as a material feedstock, chemical reductant, or fuel.

[23] Energy Flow Chart, Lawrence Livermore National Laboratory. https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2019.png.

In June 2021, DOE launched the first Energy Earthshot Initiative – Hydrogen Shot – which seeks to reduce the cost of clean hydrogen by 80% to $1 per 1 kilogram in 1 decade ("1 1 1").[24] The Hydrogen Shot Initiative is pursuing a number of existing and advanced technology pathways that have the potential to meet this ambitious goal, which will enable the widespread use of hydrogen as a clean fuel and chemical feedstock. Several of these technology pathways are enabled by low-cost, renewable, high-temperature heat and are well-suited for integration with CST, as discussed below.

An interesting application of CST is the production of energy-dense liquid or solid fuels production using solar energy, without fossil fuel precursors, as an alternative to electricity production and long distance transmission. The high energy density of fuels – for example, 9.9 kWh/L for diesel, 9.7 kWh/L for gasoline, or 4.4 kWh/L for methanol – leads to very low transportation costs of approximately $5/MWh for every 1000 miles, by railcar, or even less by pipeline.[25] The ability to transport dense solar-derived fuels, at low cost, is an attractive strategy to provide decarbonized energy to locations, especially beyond the US Southwest, that may not have an appropriate solar resource, or land availability, for direct solar thermal energy utilization.

High-temperature industrial reactors are carefully designed and optimized for heating with fuels, making it impossible to simply substitute concentrated sunlight into existing reactor designs. For solar purposes, it is useful to divide reactors between on-sun receiver-reactors that are directly heated by sunlight and indirectly heated reactors that use energy from TES systems[26]. In either case, fuels could potentially be used to complement solar heat input, while still replacing the vast majority of fuel utilization compared to a conventional reactor. Among other considerations, the design of an on-sun receiver-reactor should consider variability in solar irradiance, cloud transients blocking solar input, variable wind speeds increasing convective heat losses, and inaccuracies in heliostat aiming and operation. If process heat is not consistently delivered to the reactor, reactor shutdown, escalation, or runaway reactions may occur, making reactor control difficult. By comparison, an indirect reactor strategy collects energy at the solar focus, then transfers it to a secondary heat transfer and/or thermal storage media, which is then used in a separate system to affect a thermochemically driven reaction. Indirect reactors may be preferred for better chemical control, although they may introduce additional losses due to heat transport and storage.

[24] https://www.energy.gov/eere/fuelcells/hydrogen-shot

[25] Based on a typical cost of rail transport of $0.04 per ton-mile; https://www.bts.gov/content/average-freight-revenue-ton-mile

[26] Zsembinszki, Gabriel, Aran Solé, Camila Barreneche, Cristina Prieto, A. I. Fernández, and Luisa F. Cabeza 2018. "Review of Reactors with Potential Use in Thermochemical Energy Storage in Concentrated Solar Power Plants" Energies 11, no. 9: 2358. https://doi.org/10.3390/en11092358.

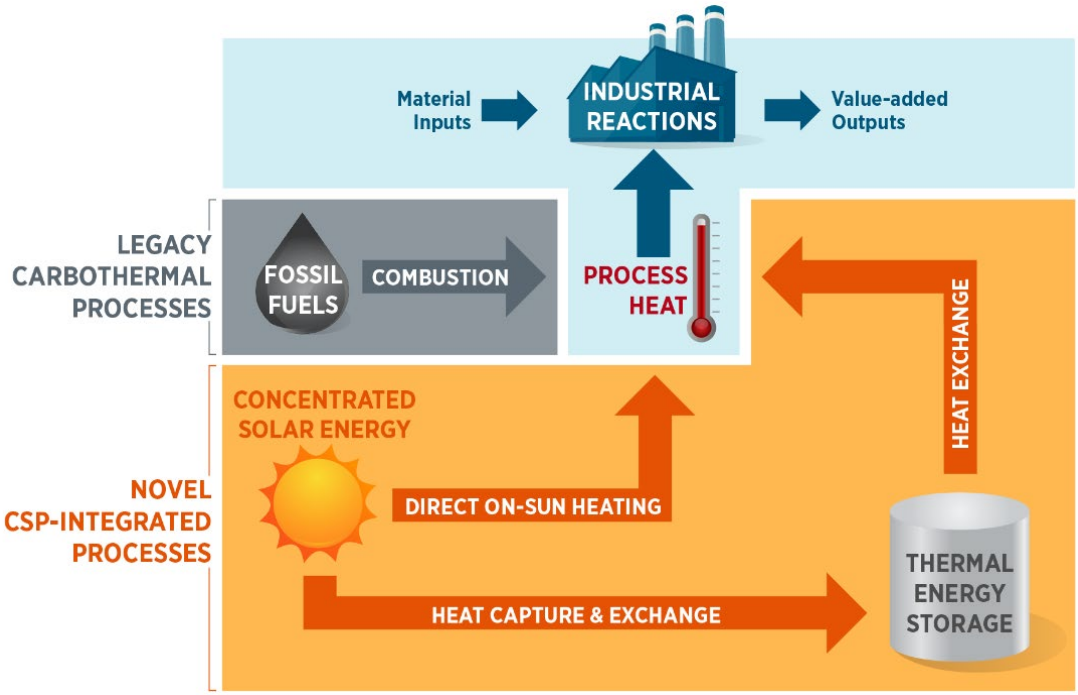

Figure 6: Conceptualized replacement of fossil energy by CST leading to reduction/elimination of emissions

This topic seeks to develop solar-driven processes using directly heated on-sun reactors, indirectly heated TES-coupled reactors, recuperators for heating and cooling reactants and products, and/or the production and use of low-carbon fuels for use as a heat source or chemical reactant. When relevant, catalyst addition and renewal must be considered.

Regardless of the specific process application, there are a number of considerations that applicants should explicitly consider in their proposed technologies

Consistent Plant Operation*:* Most of the relevant industrial processes involve high capital cost equipment that must be operated at high capacity factor to recoup investment costs. Applicants should clearly describe how their proposed technology is either consistent with, or enables, facility operation near 24 hours per day, either using TES, or via hybrid-grid-supported operation. Proposals that hybridize with conventional fossil-fuel-driven operation are also of interest, if applicants can show that their innovation would substantially reduce GHG emissions. Applicants are encouraged to consider how the materials handling stream could be included into an energy storage scheme. Inventory management and storage/control costs should be included in any techno-economic analyses.

Industrial Relevance**:** Applicants should explicitly scope their projects to ensure that their proposed technologies are consistent with industry and market requirements. Applicants are strongly encouraged to form an industry advisory panel as part of their application. Proposals should plan to validate that the product generated through the proposed solar-thermal driven process is equivalent to, or otherwise an acceptable market replacement, of conventional product. Additionally, applicants should, to the extent possible, consider the

geographic distribution of existing supply chains. Technoeconomic analyses should account for transportation costs of raw materials to the regions of appropriate solar resource.

Reactor Design and Control: Distribution of heat from CST or TES into reactants may present challenges in achieving a uniform, homogeneous, and sufficient extent of reaction through the reactor volume. Mass transfer, heat transfer, temperature, pressure, kinetics, pumping, separations, parasitic losses, applied electrical potential, and thermodynamics of operation should be considered by applicants as appropriate. Additionally, proposals should also account for potential product degradation and difficulties in reactor control, due to the fast chemical kinetics at high temperature.

Conventional reactors can be classified[27] as batch reactors, continuous stirred-tank reactors (CSTR), or plug flow reactors (PFR). However, for solar thermochemical applications, researchers have primarily focused on stacked, entrained, and fluidized beds.[28] In this description, stacked beds include packed beds, moving beds, and rotating (centrifugal) beds. Fluidized beds refer to both gas-fluidized and air blown beds. Entrained beds include cyclone and pneumatic configurations. Both thermal decomposition and solid–gas chemical reaction processes have been investigated in experimental reactors. All designs have potential advantages and disadvantages, ranging from their ability to accommodate direct solar flux, potential integration with TES, achievable ranges of volumetric heat and mass transfer, and suitability towards high-temperature heat transfer media.[29] A summary comparison of performance of selected reactor types is provided in **Table 1** below. Fluidized bed reactors may hold particular interest due to their combination of well controlled heat transfer, and potential for integration with particle receivers currently under development.[30]

Table 1: Comparison of Reactors for Solar Thermochemical applications

Reactor Type	Advantages	Disadvantages
Fixed/Packed Bed	Low cost/Low parasitic energy requirement Simple models for control	Low heat and mass transfer High pressure drop Implementation difficulty in receiver cavity Stacked beds needed in cavity Irradiance distribution non-uniform

[27] Luyben, William L., Chemical reactor design and control, John Wiley & Sons, Inc (2007).
[28] Zsembinszki, Gabriel, Aran Solé, Camila Barreneche, Cristina Prieto, A. I. Fernández, and Luisa F. Cabeza 2018. "Review of Reactors with Potential Use in Thermochemical Energy Storage in Concentrated Solar Power Plants" Energies 11, no. 9: 2358. https://doi.org/10.3390/en11092358.
[29] Clifford K. Ho, Jeremy Sment, Kevin Albrecht, Brantley Mills, Nathan Schroeder, Hendrick Laubscher, Luis F. Gonzalez-Portillo, Cara Libby, John Pye, Phillippe Gunawan Gan, and Ye Wang, "Gen 3 Particle Pilot Plant (G3P3) – High-Temperature Particle System for Concentrating Solar Power (Phases 1 and 2)," SAND2021-14614, November (2021), https://energy.sandia.gov/wp-content/uploads/2021/11/SAND2021_G3P3_Phases1and2_v7_clean.pdf.
[30] Tregambi, Claudio,Troiano, Maurizio, Montagnaro, Fabio,Solimene, Roberto, Salatino, Piero, "Fluidized Beds for Concentrated Solar Thermal Technologies—A review", 2021, 10.3389/fenrg.2021.618421, https://www.frontiersin.org/article/10.3389/fenrg.2021.618421

Moving bed	Increase in heat transfer coefficient; direct contact possible	Difficulties in implementation in receiver Non-uniform irradiance Residence time control difficult for reaction
Rotary	High chemical conversion due to high heat and mass transfer Versatility Long life components	Scalability difficult Parasitic energy increased due to rotation Thermomechanical component lifetime
Fluidized bed	High heat and mass transfer coefficients Minimization of hot spots and instability	Implementation challenge in receiver Need for gas for fluidization Parasitic energy requirement Erosion of internals Complex hydrodynamics necessitating complexities in reaction control

Materials: Thermomechanical property limitations may limit the potential operating regime, especially for concepts that employ enclosed receivers/reactors – potentially at high pressure. Applicants should clearly address materials of construction, including (for example) creep and creep-fatigue interactions due to diurnal cycling. Proposals should identify any needed R&D on materials development, manufacturing, fabrication, or joining.

Technical Areas of Interest

The following industrial processes are of particularly high priority for this Topic, due to their relative contributions to carbon emissions. However, applicants may submit proposals for CST integration with other high temperature processes that may be relevant to other industrial applications. Proposals should justify that their technology will have a significant impact on industrial fossil fuel consumption and/or CO_2 emissions.

Hydrogen Production

This Topic seeks to advance two primary objectives for hydrogen production:

- The development of subcomponents for eventual demonstration and deployment of CST-heated hydrogen production systems, or hydrogen production subsystems as part of an integrated liquid solar fuels production facility.
- System design and optimization of high-temperature steam electrolysis (HTSE) systems closely integrated with TES – either with existing nitrate salts or advanced, high-temperature thermal storage media like solid particles, molten chlorides, or others.

In the near-term, HTSE is a particularly interesting approach to high-efficiency hydrogen generation. This technology uses solid oxide electrolysis cells (SOECs), using steam (typically above 500 °C) and operates at relatively high electrical efficiency as compared to other

electrolysis technologies.[31] Hydrogen could potentially be produced using any combination of CST and electricity from CSP, other renewable resources, or the grid, with the generated H_2 used directly in steel manufacturing, ammonia synthesis, or other chemicals production.

Solid oxide electrolysis is a relatively mature technology that has made significant advances in laboratory scale demonstrations in recent years and is in the early stages of commercialization. SOECs are particularly promising because they do not require the high-cost platinum- or iridium- based catalyst materials needed in low-temperature proton exchange membrane electrolyzers. DOE's Hydrogen and Fuel Cells Technologies Office (HFTO) has developed targets for cost-effective high temperature electrolysis deployed at commercial scale.[32] However, applicants are encouraged to propose concepts for the efficient thermal integration of MW-scale SOEC with steam generated from TES, with a focus on the development of recuperators to enable highly efficient and scalable systems. Electrolyzer stacks at a 5 MW_e scale would likely require integration with TES that can deliver 1 MW_{th} (approximately 1.3 tonnes of steam per hour). Needed development includes both primary heat exchangers, which would be expected to generate low pressure steam (less than 10 bar) with heat input above 550 °C from TES, as well as recuperators, which would recover heat from hydrogen and oxygen exiting the electrolyzer. Integrated system analyses (with appropriate heat and mass balances) should be provided by applicants, as operation of recuperators with TES requires detailed analysis of how and when heat is supplied and delivered to TES or input steam. Given the maturity of these technologies, proposals should address Tier 2 and 3 objectives and scale.

Beyond electrolysis, other low-TRL pathways towards solar thermal hydrogen production are of interest in this topic, particularly thermochemical water splitting (TWS) processes that employ chemical looping, for example, via redox material systems.[33] However, applications focused on TWS should go beyond materials-level catalyst development, which is supported by HFTO. Proposals should address innovative integrated system concepts with commercial relevance, at the Tier 1 or 2 level.

Cement Production

The production of cement is a complex multistep process[34] that involves three distinct steps of converting limestone-bearing feed, including:

- Preheating to calcination temperature – room temperature to approximately 660°C

[31] See Table 2 of DOE Hydrogen and Fuel Cells Program Record #20006 (https://www.hydrogen.energy.gov/pdfs/20006-production-cost-high-temperature-electrolysis.pdf). Note the 98% Stack Conversion Efficiency (% Lower Heating Value H2) under Stack Electrical Usage (kWh/kg).
See also Table 2 on page 5 of Hydrogen Production Cost From PEM Electrolysis Program Record # 19009 (https://www.hydrogen.energy.gov/pdfs/19009_h2_production_cost_pem_electrolysis_2019.pdf). Note the <70% Stack Conversion Efficiency (% Lower Heating Value H2) under Stack Electrical Usage (kWh/kg).
[32] David Peterson, James Vickers, Daniel DeSantis, DOE Hydrogen and Fuel Cells Program Record #: 20006, Hydrogen Production Cost From High Temperature Electrolysis – 2020. https://www.hydrogen.energy.gov/pdfs/20006-production-cost-high-temperature-electrolysis.pdf
[33] https://www.energy.gov/eere/fuelcells/hydrogen-production-thermochemical-water-splitting
[34] Chapter 2, Technology of Cement Manufacture, "Technology Roadmap - Low-Carbon Transition in the Cement Industry,", IAEA report (2019), https://www.iea.org/reports/technology-roadmap-low-carbon-transition-in-the-cement-industry

- Calcination, or decarbonation, of calcium carbonate ($CaCO_3$) – up to approximately 900°C
- Calcination completion and sintering of calcium oxide (CaO) – up to approximately 1450°C

Since the feedstock typically consists of components other than $CaCO_3$, including dolomite, alumina, and iron oxide, several other competing reactions occur (see Table 2 below for selected reactions and reaction energy), necessitating careful control of temperature to ensure a consistent product. The multiple steps and requirement for uniform heat input complicate the options for complete integration of CST with cement. While preheating the feed to calcination temperature range is feasible using CST, a more thorough understanding of the calcination process, and design of solar-heated calciners is required. The heat input for calcination typically needs to be administered in a narrow temperature band to avoid overshooting, sintering and incomplete calcination. The final step, sintering, requires very long residence times and temperatures that are difficult to achieve given currently available materials and receiver designs. However, one advantage of solar-heated calcination is that the product, referred to as clinker, can be readily stored and used for TES before further processing in the sintering step. SETO has previously supported relevant work on closed-cycle calcium oxide-calcium carbonate thermochemical energy storage[35] that provides insight into driving calcination with solar thermal input. The aim of this technical area is to enable the design, and eventual on-sun testing, of a solar heated calciner, enabling calcination of limestone, above 920 °C, to produce clinker at a sufficiently fast rate for industrial processing. Although calcination of $CaCO_3$ has the largest potential market and opportunity for industrial decarbonization, calcination of a variety of other metal carbonates is relevant to several additional smaller, niche applications, and may have benefits as early markets.

Table 2: Details of energy input and reactions at various temperatures and equipment

Equipment	Reaction	Reaction energy (kj/kg-clinker)	Sensible Heat input (kj/kg-clinker)
Preheater, 25-850°C	65-125°C: Evaporation of free water	Per water content	736
	400-650°C: Clay decomposition	42.2 kJ/kg	
	500-650°C: Dolomite decomposition	19.7 kJ/kg	
	700-900°C: Alumina and iron oxide react	207.2 kJ/kg	

[35] Muto, Andrew, and Hansen, Tim A. 2019. "Demonstration of High-Temperature Calcium-Based Thermochemical Energy Storage System for use with Concentrating Solar Power Facilities". United States. https://doi.org/10.2172/1501361 https://www.osti.gov/servlets/purl/1501361

Calciner, 25-850°C	650-900°C: Low temperature calcium carbonate decomposition	722.5 kJ/kg	90
Kiln, 900 - 1,400°C	900-1,050°C Remaining calcite decomposition	601.9 kJ/kg	400
	1300-1425°C Sintering	69.3 kJ/kg	
Clinker Cooler, 1,400-25°C	Cooling clinker to room temperature		-1,072

Several conceptual designs of solar calciner have been proposed and developed, including fluidized bed calciners[36], gas suspension calciners[37], and rotating kilns[38], but have not yet generated steady-state operational data at relevant scales and low thermal efficiencies. For any calcination reactor design, a careful design of kinetics, reactor flow modeling, consideration of residence times, heat transfer, and fluid dynamic analyses of heat transfer media will be needed to design a solar calciner.

Proposals responding to Tiers 2 or 3 should provide a clear strategy to eventually test an on-sun solar calciner at a scale of approximately 1 kg/s of clinker feed heated to above 900 °C, under a partial pressure of approximately one atmosphere of CO_2, and targeting at least 60% extent of calcination.

The discussion above does not preclude other, innovative proposals for integration of CST with cement manufacturing, including innovative rotary kiln and non-conventional cement production, including material substitutions for clinker material. Innovative re-designs of these processes are encouraged as Tier 1 or 2 applications.

Steel Production

Steel production is dominated by two primary technologies, namely; 1)blast furnace which is a basic oxygen furnace (BF-BOF) and 2) electric arc furnace (EAF). BF-BOF produces steel from iron ore, while EAF takes scrap iron and direct-reduced iron (DRI) as input for melting.

[36] Thibaut Esence, Emmanuel Guillot, Michael Tessonneaud, Jean-Louis Sans, Gilles Flamant, "Solar calcination at pilot scale in a continuous flow multistage horizontal fluidized bed," Solar Energy, Volume 207, 1 September 2020, Pages 367-378.

[37] Tom Hills, Pilar Lisbona, Simon Thomsen, Luis Romeo, Mark Sceats, Carlos Ortiz, Solar Calcium-looping integration for Thermo-Chemical Energy Storage, SOCRATCES Project DELIVERABLE D3.4, Solar Calciner Design, https://socratces.eu/wp-content/uploads/SOCRATCES_D3.4_Solar-Calciner-Design.pdf

[38] Gkiokchan Moumina, Maximilian Rysselb, Li Zhaob, Peter Markewitz, Christian Sattler, Martin Robinius, Detlef Stolten, "CO2 emission reduction in the cement industry by using a solar calciner," Renewable Energy, 2020, 1578-1596, https://doi.org/10.1016/j.renene.2019.07.045

The use of fossil fuels, and generation of CO_2, are significant, especially for the BF-BOF process.

A number of potential opportunities exist for integration of CST technologies with steel-making. To reduce the direct generation of CO_2 in the process, industry is actively developing and demonstrating the production of DRI with hydrogen as a reductant. As discussed above, there may be opportunities to lower the cost of hydrogen production using CST, but thermal energy is also required to pre-heat iron ore pellets to approximately 850 °C. Integrated system concepts may also be able to use hot DRI as a TES medium, either for dispatchable heat to down-stream processes or for electricity generation.

In this technical area, SETO is particularly interested in Tier 2 or 3 innovative concepts to enable a near term pilot scale facility for the demonstration of direct reduction of iron using CST and hydrogen. Specifically, research is sought on the design of preheaters or DRI reactors that directly use CST in an on-sun reactor, or indirectly use TES. Proposed designs should account for the limitations of typical iron ore pellet size, approximately 3 to 15 mm. Applications addressing this technical area should describe how they can achieve target metrics for direct reduction pellet preheating including: 436 kW_{th}/tonne steel;[39] assuming 1:1.65 ratio between steel and ore, a target for preheating to reduction temperatures is 700 kW_{th}/tonne iron ore; 850 kW_{th}/tonne solar energy with 80% receiver efficiency. The target for heating hydrogen (from electrolysis and recycled top gas) varies with the efficiency of reduction. The heat required can vary from 91-367 kwh/kg of steel; which corresponds to 150-600 kWh/kg iron ore.

Although the above discussion focuses on CST integration with DRI production, other innovative concepts are also welcome. For example, the direct electrolysis of iron oxides may present an alternative low-carbon route to iron production. As the process temperature demands for such routes vary substantially depending on the electrolyte system, the outlook for CST compatibilization with iron electrosynthesis must be assessed on a case-by-case basis.[40] Ongoing research thrusts range from low-temperature aqueous electrowinning at 110 °C to the electrolysis of molten iron oxides at over 1600 °C.[41,42] Assuming such approaches afford novel opportunities for CST integration, SETO is interested in Tier 1 or 2 concepts that may serve to address long-standing technical challenges in this field, such as the development of inexpensive, carbon-free inert anodes for oxygen evolution in corrosive oxide melts.

Chemical Production

[39] Bhaskar A, Assadi M, Nikpey Somehsaraei H. Decarbonization of the Iron and Steel Industry with Direct Reduction of Iron Ore with Green Hydrogen. Energies. 2020; 13(3):758. https://doi.org/10.3390/en13030758
[40] Cavaliere P. (2019) Electrolysis of Iron Ores: Most Efficient Technologies for Greenhouse Emissions Abatement. In: Clean Ironmaking and Steelmaking Processes. Springer, Cham. https://doi.org/10.1007/978-3-030-21209-4_10
[41] Junjie Y (2018) Progress and future of breakthrough low-carbon steelmaking technology (ULCOS) of EU. Int J Miner Process Extract Metall 3(2):15–22. https://doi.org/10.11648/j.ijmpem.20180302.11
[42] Allanore A, Ortiz LA, Sadoway R (2011) Molten oxide electrolysis for iron production: identification of key process parameters for largescale development. In: Energy technology 2011:carbon dioxide and other greenhouse gas reduction metallurgy and waste heat recovery. Wiley, Hoboken, NJ, pp 120–129

The US chemical industry covers a wide variety of processes, and includes more than 70,000 products, 11,000 manufacturers, and 544,000 jobs.[43] It is also the largest emitter of CO_2 in the US industrial sector (over a billion tonnes) and the largest consumer of fossil fuel, both as feedstock and source of heat and power (11,122 TBTu). Among others, the sector includes petrochemicals, nitrogenous fertilizers, organics, inorganics, and fuels, out of which ammonia, fuels and petrochemicals are of particular interest for the range of CST temperatures and heat input. Endothermic reactions such as dehydrogenation and cracking are of specific interest, though any industrial reactivity demanding high process temperatures has potential merit for studying CST compatibility.

Ammonia: Ammonia production is industrially performed in a two stage process: hydrogen production, typically by steam methane reforming, followed by ammonia synthesis through the century-old Haber–Bosch reaction. The first step encompasses primary and secondary steam methane reforming reactors (SMR), followed by a two-stage water–gas shift reactor, CO_2 removal, and methanation. The addition of air to SMRs also provides the stoichiometric nitrogen required for the Haber–Bosch reaction. The SMR process also generates steam, which is typically utilized mostly to drive gas compression. The SMR output is a mixture of carbon monoxide, hydrogen, unreacted steam and methane, which is introduced into the water–gas shift (WGS) reactor. The WGS reaction is exothermic, and heat must be removed to minimize CO.

In the Haber–Bosch reactor, hydrogen and nitrogen are typically reacted at 15–25 MPa and 400–450 °C over an iron-based catalyst. The current energy requirement is 27-32 gigajoules (GJ) per tonne,[44] and CO_2 is generated at a rate of 1.6 tonnes per tonne of ammonia. The primary method often suggested for reducing CO_2 emissions is via hydrogen produced from electrolysis, integrated with nitrogen from an air separation unit (ASU), that is then reacted in a commercial Haber-Bosch reactor. Hydrogen production is discussed earlier in this topic, however other innovative concepts for CST-integration with ammonia synthesis of interest. For example, SETO-funded research has explored solar thermal ammonia production using cyclic operation of metal oxide and metal nitride. In contrast to the energy requirement of 30 GJ per tonne for the Haber-Bosch process, a much lower energy requirement of 7.7 GJ per tonne has been suggested.[45] However, reliable and efficient receiver-reactor designs, and fully integrated system concepts have not yet been developed, although outlines have

[43] American Chemistry Council (ACC), The Business of Chemistry by the Numbers, June 2020. https://www.americanchemistry.com/Business-of-Chemistry-by-the-Numbers

[44] Collin Smith, Alfred K. Hill and Laura Torrente-Murcian, "Current and future role of Haber–Bosch ammonia in a carbon-free energy landscape", Energy Environ. Sci., 2020, 13, 2, 331-244, http://dx.doi.org/10.1039/C9EE02873K

[45] Series of presentations in SolarPaces 2021:
Matthew Kury, H. Evan Bush, Kevin Albrecht, and Andrea Ambrosini, "Modeling of Concentrating Solar Reduction Reactor for Oxygen Separation from Air"
Tyler Farr, Nhu Nguyen, H. Evan Bush, Andrea Ambrosini, and Peter G. Loutzenhiser, "Experimental Screening of Singly- and Doubly-Substituted Strontium Ferrites for Solar Thermochemical Air Separation".
Alberto de la Calle, H. Evan Bush, Ivan Ermanoski, Xiang Gao, Andrea Ambrosini, and Ellen B. Stechel ,"Solar-driven nitrogen separation process from air based on two-step thermochemical cycle: thermodynamic analysis".
H. Evan Bush, N. Ty Nguyen, Tyler P. Farr, Ellen Stechel, Peter G. Loutzenhiser, and Andrea Ambrosini.
Xiang Gao, Ivan Ermanoski, Andrea Ambrosini, Alberto de la Calle, and Ellen B. Stechel. "A Low-pressure Reactor Design for Solar Thermochemical Ammonia Production".

been presented. Proposals are welcome for innovative technologies, particularly at Tier 1 or 2 levels, for CST integration with ammonia production pathway.

Fuels: A particularly important sub-category of chemicals are energy-dense liquids or solids that could allow cost-effective long-distance transportation of stored solar energy. In addition, key transportation markets such as aircraft and maritime transport are likely to continue to require fuels for the foreseeable future. Existing research and industrial development is making progress on production of chemical feedstocks, like hydrogen and CO_2, through renewable energy resources. CST is a potentially attractive strategy to provide the emissions-free heat needed for the thermochemical transformations that can convert those feedstocks into liquid fuels.

Different pathways have been suggested for liquid fuels using CST in the literature, though all begin with CO_2 and either H_2O or H_2. The catalytic 'reverse water-gas shift' (RWGS) reaction – which converts CO_2 and H_2 into CO and H_2O – can be used to produce syngas. By adding more H_2 in the feed, syngas output can be produced at various proportions for further Fischer-Tropsch (FT) synthesis, which is a well-established process to produce liquid hydrocarbon fuels compatible with the existing gasoline and diesel infrastructure. FT reactors typically operate at 230-240 °C and 25-40 bar.

At low reaction temperatures, the mildly endothermic RWGS reaction competes with methanation, which is thermodynamically favored. However, at the high temperatures of CST (~700 °C), the catalytic RWGS reaction is favored. Some opportunities for research and development include the integration of CST with RWGS (with heat extraction from the product stream to heat the inlet stream using gas-gas recuperators), the increasing of CO_2 conversion and CO selectivity with excess hydrogen feed to avoid recycling, and the identification of catalysts to enable on-sun reactivity.

Other potential pathways of interest include processes that produce CO and H_2 through thermochemical splitting of CO_2 and H_2O via a reduction-oxidation (redox) cycle driven by concentrated solar radiation.[46] Although most research thus far has focused on nonstoichiometric ceria ($CeO_{2-\delta}$) due to its demonstrated stability, production of other redox materials such as perovskites and hercynite spinels may warrant further study. For ceria catalysts, the redox cycle is a two-step process. In the endothermic step, ceria is thermally reduced to generate O_2, and in the second exothermic step, the reduced ceria is re-oxidized with CO_2 and/or H_2O to generate CO and/or H_2. Ceria is thus not consumed and the net overall reaction generates syngas (H_2:CO) and O_2 in separate steps. However, this process has significant challenges to commercialization, due to the very low net solar-to-fuel conversion efficiency of 3-5% and the high temperatures required by the ceria-catalyzed system (approximately 1400 °C).

Applicants addressing this technical area should clearly describe a strategy to enable production of a commercially relevant liquid or solid fuel using CST. Proposals should clearly define the targeted fuel, and describe the full system, including reactors, catalyst regeneration and recycling, heat integration between CST and the reactor, and (if needed to

[46] Schäppi, R. et al. Drop-in Fuels from Sunlight and Air. Nature, https://doi.org/10.1038/s41586-021-04174-y (2021).

avoid reactor transients) TES integration. While some potential pathways are outlined above, any credible concept for fuel synthesis is encouraged at the scale of Tier 1, 2, 3, as appropriate for the maturity of the concept.

Many smaller scale processes in the chemical industry are a temperature range well suited to heating by CST. For these high TRL chemistries, the goal is to supply heat from CST with minor changes to reactor geometry as a first-in-kind early entrant of CST to process industry. Some specific examples are discussed below. These are meant to be illustrative, and do not exhaustively represent all potential subjects of interest under this topic.

Dehydrogenation of ethylbenzene to styrene: Direct dehydrogenation of ethylbenzene to styrene accounts for most commercial production. The reaction is carried out in the vapor phase with steam over an iron oxide catalyst. The reaction is endothermic (124.9 kJ/mol of ethylbenzene) and the reactor can be adiabatic or isothermal. Because two moles of gaseous product are formed for each mole of reactant, low pressure favors the forward reaction.[47] [48] Steam reduces the partial pressure of ethylbenzene and favors the production of styrene, as well as supplying the required 124.9 kJ/mol heat of reaction, and cleans the iron catalyst. Low pressure steam limits energy input into the reactor, and additional heat may be needed from solar thermal to displace fossil fuel use. In contrast, an isothermal reactor heats the steam/ethylbenzene mixture in a tube packed with catalysts with hot gases on the shell side. In either type of reaction system, low pressure steam and heat needs for the process can be met with CST. Modifications to reactor design to fit with thermal energy storage system of a CSP plant may be required to integrate styrene production with concentrated solar thermal.

Dehydrogenation of light alkanes to olefins:The direct dehydrogenation of propane to propylene is endothermic (124 kJ/mole propane; 143 kJ/mole of *iso*-butane), performed over a chromia or platinum/tin catalyst, with inlet temperature between 570-650°C depending on the commercial process.[49] Reactors typically utilize a series of charge and inter-stage heaters fired using natural gas that supply heat. Chromia-alumina or Pt-Sn/Alumina catalysts are used in adiabatic and isothermal, moving and fixed bed, with heat supplied by reactor heating, interstage heating and catalyst regeneration. For a variety of commercial process flow charts, the system pressure is low at 0.5-2 bars, and temperature varies from 570-640 °C, which potentially integrates well with hot air and/or steam from CST.

The dehydrogenation of butane is a similar reaction to propane and uses similar reactor systems in series. The catalytic dehydrogenation of *n*-butane[50] is a two-step process, from *n*-

[47] James, D. H.; Castor, W. M. Styrene. In Ullmann's Encyclopedia of Industrial Chemistry; Campbell, F. T.,Pfefferkorn, R.,Rounsaville, J. F., Eds.; Wiley-VCH: Weinheim, 1994; Vol. A25, p. 329.
[48] Kochloefl, K. Dehydrogenation of Ethylbenzene. In Handbook of Heterogeneous Catalysis; Ertl, G.,Knozinger, H.,Weitkamp, J., Eds.; VCH: Weinheim, 1997.
[49] Peng Bai, Daolan Liu, Pingping Wu, and Zifeng Yan, "Catalytic Dehydrogenation of Propane to Propene: Catalyst Development, Mechanistic Aspects and Reactor Design," Reviews in Advanced Sciences and Engineering Vol. 3, pp. 180–195, 2014.
[50] Nawaz, Zeeshan. "Light alkane dehydrogenation to light olefin technologies: a comprehensive review" Reviews in Chemical Engineering, vol. 31, no. 5, 2015, pp. 413-436. https://doi.org/10.1515/revce-2015-0012

butane to *n*-butenes and then to butadiene. Both steps are endothermic. In the Houdry Catadiene process, *n*-butane is dehydrogenated over chromium/alumina catalysts in reactors operating at low pressure and approximately 600-680 °C.

Due to the complexity of side reactions, and the need to cool products, detailed analysis and simulation is likely needed to redesign dehydrogenation reactors for CST integration. As a drop-in replacement of fossil fuel, reactor design for solar thermal energy needs careful consideration of heat transfer, reactant residence time, and catalyst handling.

Steam cracking/pyrolysis of ethane/propane/naptha: Hydrocarbon feedstocks are cracked[51] by heating to >850°C with a typical heat demand of 1.4 to 1.6 MW_{th} per tonne. Steam is generated by fired heaters, mixed with feed and heated to > 850 °C. Replacement of fired heaters using solar energy can eliminate fossil fuel consumption and associated emissions. However, careful redesign of solar energy input and reactor size will be needed to attain conversion rates as required and to avoid coking.

While the discussion above has focused on select process areas of particular emphasis, they only cover a fraction of the industrial processes that may be driven by CST. Proposals that address any relevant processes and products are encouraged to apply to this topic. However, this topic is intended to develop innovative, solar-thermal driven industrial processes. Proposals that couple mature solar thermal collectors for supplying process steam (< 40 bars/250 C), with no additional innovation, are **not of interest.**

ii. Topic Area 2: Concentrating Solar-thermal Particle Technologies for Generation 3 CSP and Beyond (Gen3++)

Introduction

Solid particles have a number of advantages as high-temperature (>700 °C) heat transfer media (HTM) and TES materials. Relative to alternative pathways based on liquids, gases, or supercritical fluids, particle-based systems require fewer components and are less complex to operate. Additionally, particle-based systems need relatively few high-cost materials to collect and transport thermal energy. TES using solid particles is expected to be highly cost-effective due to stability at high service temperatures and the relatively low cost of the material. These factors could increase plant availability and reliability, and enable simpler plant construction and commissioning. In addition, heated solid particles can be stored and used as needed for electricity production, process heating, thermochemistry, and solar fuels production.

SETO is currently funding a MW-scale pilot of a fully integrated solar particle system that includes all the primary (or required) components such as receivers,[52] storage, and primary heat exchangers, as well as ancillary components including particle elevators and flow

[51] Tao Ren, Martin Patel, Kornelis Blok, "Olefins from conventional and heavy feedstocks: Energy use in steam cracking and alternative processes." Energy 31 (2006) 425–451.
[52] Generation 3 Concentrating Solar Power Systems (Gen3 CSP) Phase 3 Project Selection, https://www.energy.gov/eere/solar/generation-3-concentrating-solar-power-systems-gen3-csp-phase-3-project-selection

control valves. In this system, small diameter particles (less than 1 mm in diameter) fall freely through an open receiver and are heated by a beam of concentrated sunlight. Heat from solid particles is removed using a sCO_2 heat exchanger. A power block is not currently being integrated with the heat exchanger in the existing pilot system; opportunities for integration of TES with the sCO_2 power block are discussed later.

Initial R&D at Sandia National Laboratories (SNL) by Hruby and coworkers[53] has been followed by more recent SETO-funded research on falling particle receivers.[54] For example, SETO has funded the investigation of two different receiver designs,which have been tested on-sun: a free-fall and an obstructed flow configuration. On-sun testing of the free-fall particle receiver design showed that the particle temperatures increased by 50-200 °C per meter of illuminated drop length for mass flow rates ranging from 1 to 7 kg/s per meter of particle-curtain width and for average irradiances up to ~ 700 kW/m^2. Higher temperatures were achieved at the lower particle mass flow rates. The obstructed flow design yielded particle temperature increases over 300 °C per meter of illuminated drop length for mass flow rates of 1 – 3 kg/s per meter of curtain width for irradiances up to ~1,000 kW/m^2. Peak particle temperatures greater than 900 °C were achieved with bulk particle outlet temperatures reaching 800 °C. The thermal efficiencies of both designs reached 70 – 80% at higher irradiances and mass flow rates. Further research has enabled control of mass flow rates of particle receiver for various irradiances.[55]

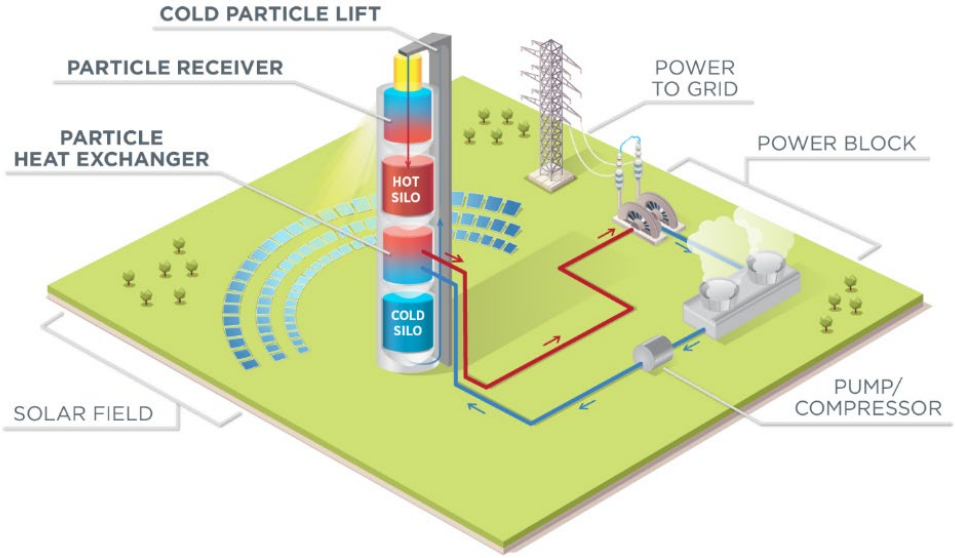

Figure 7. General design of a particle based CSP system; several forms of particle receiver shape, design and layout of silos, heat exchanger and intermediate lift are feasible; power block is a representation

[53] Falcone, P K, Noring, J E, and Hruby, J M. Assessment of a solid particle receiver for a high temperature solar central receiver system," SAND85-8208,1985. Web. doi:10.2172/6023191

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

[55] 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.

Subsequent research as part of the Gen3 CSP program led to the detailed engineering design of a 2 MW_{th} receiver integrated with a 1 MW_{th} integrated TES/heat exchanger system.[29] Research conducted as part of this program resulted in design optimization of the falling particle receiver geometry. Such geometric improvements were in response to earlier findings that an open receiver geometry was highly impacted by wind direction and velocity.

There are several solid particle receiver designs that have been explored by the research community,[56] which can be classified into three types:

- Direct receivers, including free falling receivers, obstructed flow receivers,[57] rotating receivers[58] and fluidized (in-tube, enclosed) receivers;
- Indirect receivers, comprised of a heat exchanger receiver where tubes heat the particles;
- Fluidized bed receivers, where a black absorbing surface heats a fluidized bed of particles.[59]

The choice of solid particle receivers opens up a number of system-level design considerations, especially due to the unique advantages of the wide temperature ranges enabled by solid particles. Parametric analyses have studied the influence of upper and lower HTM temperatures on LCOE, [60] [61] and suggest that a high temperature difference may lead to reduced LCOE. The most important factors for this reduction are the cost decrease of particle inventory, storage containment size, and particle-to-fluid primary heat exchanger. The results indicate that there may be unique advantages to the use of solid particles for high-efficiency steam power cycles or sCO_2 cycles that are designed to tolerate a large ΔT. For example, sCO_2 cycle designs have been considered that incorporate a high-temperature recuperator bypass cycle with a boiler inlet temperature of 192 °C, turbine inlet temperature of 620°C, and efficiency of 42.19% (increasing to 47.5% at a turbine inlet temperature of 750°C).[62] Alternate cycles such as partial cooling with reheat have also been

[56] Calderón, A, Barreneche, C, Palacios, A, et al. Review of solid particle materials for heat transfer fluid and thermal energy storage in solar thermal power plants. Energy Storage. 2019; web. Doi: https://doi.org/10.1002/est2.63.

[57] Hany Al-Ansary, Abdelrahman El-Leathy, Sheldon Jeter, Eldwin Djajadiwinata, Shaker Alaqel, Matthew Golob, Clayton Nguyen, Rajed Saad, Talha Shafiq, Syed Danish, Said Abdel-Khalik, Zeyad Al-Suhaibani, Nazih Abu-Shikhah, Mohammad I. Haq, Ahmed Al-Balawi, and Fahad Al-Harthi, "On-sun experiments on a particle heating receiver with red sand as the working medium", AIP Conference Proceedings 2033, 040002 (2018) https://doi.org/10.1063/1.5067038

[58] Miriam Ebert, Lars Amsbeck, Jens Rheinländer, Bärbel Schlögl-Knothe, Stefan Schmitz, Marcel Sibum, Ralf Uhlig, and Reiner Buck, "Operational experience of a centrifugal particle receiver prototype", AIP Conference Proceedings 2126, 030018 (2019) https://doi.org/10.1063/1.5117530

[59] http://next-csp.eu/documents/

[60] Buck, Reiner, Giuliano, Stefano, "Impact of solar tower design parameters on sCO2-based solar tower plants," 2nd European sCO2 Conference 2018. https://doi.org/10.17185/duepublico/46098

[61] Reiner Buck, and Stefano Giuliano, "Solar Tower System Temperature Range Optimization for Reduced LCOE," SolarPACES 2018, AIP Conf. Proc. 2126, 030010-1–030010-8; https://doi.org/10.1063/1.5117522 .

[62] https://www.sco2-flex.eu/wp-content/uploads/2019/06/D5.1-Report-on-the-nominal-design-of-different-plant-configurations-and-sensitivity-analysis-on-main-design-parameters.pdf

evaluated. Turbomachinery component designs and part load control strategies for these alternative cycles are under development.

In parallel, a design effort for a 100 kW_{th} heat exchanger intended to use particles to heat supercritical CO_2 to 700°C focused on three competing designs: a moving bed printed channel heat exchanger (PCHE), a moving bed shell and tube heat exchanger, and a fluidized bed heat exchanger. A moving bed PCHE was selected for further development, procured, and tested,[63] but the measured heat transfer coefficients in tests yielded overall heat transfer coefficients of ~35–80 W/m^2-K with four banks (including a nickel-alloy bank above the three stainless steel banks). The measured heat transfer coefficients were considerably lower than theoretically predicted. To identify the reasons of the poor performance, researchers focused on a smaller heat exchanger used to produce heat exchanger performance data for a novel 20 kW_{th} moving packed-bed heat exchanger prototype based on the design developed from the Gen3 CSP project. The prototype design implemented close plate spacing (3 mm) on the particle side, integral porting on the sCO_2 side, and pure counter-flow arrangement in single bank geometry. Overall heat transfer coefficients for the prototype heat exchanger at the design point were measured up to 300 W/m^2-K and cases using high approach temperature were measured with peak values as high as ~400 W/m^2-K.[64] SETO continues to support additional innovative efforts to optimize particle heat exchanger development, including the development of fluidized bed concepts and the use of higher-temperature ceramic and ceramic-metallic (cermet) composite materials.

Although the Gen3 pilot facility is currently under construction, the following opportunities have been identified for significant improvement beyond the baseline design that is planned to be tested:

- The 2 m^2 (1.7 m X 1.2 m) receiver design may not sufficiently derisk receiver heat transfer performance of commercial designs, which may be 500 m^2 in size. Several possible design features have been identified that may improve receiver performance, however it is still unclear how to validate design improvements to receiver efficiency, at scale.
- The moving bed heat exchanger for the Gen3 pilot facility, while not cost-optimized, is still significantly more expensive than is likely consistent with SETO's LCOE target. Strategies and designs for lowering the cost – preferably below \$300/kW_e are needed for commercial deployment.
- The sCO_2 power cycle target for the Gen3 CSP system imposes a temperature difference (ΔT) between the hot and cold particle storage bins of about 150 °C, with the inlet and outlet temperatures of the receiver set at 625 °C and 775 °C to supply 700 °C sCO_2 at the turbine inlet. This temperature difference ΔT defines the design

[63] Carlson, Matthew, Albrecht, Kevin, Ho, Clifford, Laubscher, Hendrik, and Alvarez, Francisco. High-Temperature Particle Heat Exchanger for sCO2 Power Cycles (Award 30342). United States: N. p., 2020. Web. doi:10.2172/1817287 .

[64] Kevin J. Albrecht, Hendrik F. Laubscher, Matthew D. Carlson, Clifford K. Ho, "Development and Testing of a 20 kW Moving Packed-Bed Particle-To-sCO2 Heat Exchanger and Test Facility, " Paper No: ES2021-64050, ASME 2021 15th International Conference on Energy Sustainability collocated with the ASME 2021 Heat Transfer Summer Conference, June 16–18, 2021

basis of the particle storage silo, volume of particles to be transported, and the particle lift design.

- Innovations are needed to achieve cost targets for the receiver (including cold particle lift) of $150/kWt; and for TES (including intermediate/hot particle lifts to cold bin) of 15 $/kWt-hr.
- Although the particles chosen for the Gen3 CSP pilot facility have high solar absorptivity, these proprietary manufactured particles suffer from high costs (~$1000/tonne) that dominate TES costs. With the large volume of materials to enable storage, the cost reduction of particles is a priority for future research.[65]
- There is considerable uncertainty in particle lift design and cost.[66,29] Lift designs have primarily been adapted from mining applications that lift room-temperature material over 1,000 meters. Costs per MW_{th} (integrated into receiver costs) seem to vary from $10-50/$MW_{th}$ and form a large fraction of receiver costs. Long-term reliability of any high-temperature lift system remains to be demonstrated.
- Due to their open-cavity design, falling particle receivers suffer from potential particle losses to atmosphere. A separate study[67] concluded that the estimated concentration of particulate matter under 2.5 µm and 10 µm (PM2.5 and PM10, respectively) are well under the significant impact levels utilized in regulatory air dispersion modeling. However, this study was validated only for 1-2 m^2 receivers. For commercial-scale receivers, which may be as large as 500 m^2, particle loss with current receiver designs may be significant. For centrifugal receivers, these loss factors remain unknown.

- The Gen3 pilot facility does not include sCO_2 power cycle integration, limiting the end user confidence in developing larger-scale facilities. A separate effort has been funded by the DOE to integrate sCO_2 power blocks with CSP plants. However, it is not evident that Recompression Close Brayton Cycle (RCBC) is the appropriate sCO_2 cycle for a broad range temperature input, similar to other applications such as coal, natural gas and waste heat. The RCBC cycle needs a narrow temperature of heating (~150°C) for maximum efficiency. Analyses of other cycles, such as cascaded, high temperature recuperator bypass, or precompression cycles may compromise on efficiency while delivering lower cost and operability with a broader particle temperature range. If the efficiency targets are compromised, cost reduction of the power block may be a way to achieve LCOE targets.

[65] Kevin J. Albrecht, Matthew L. Bauer, Clifford K. Ho, "Parametric analysis of particle CSP system performance and cost to intrinsic particle properties and operating conditions," ES2019-3893, Proceedings of the ASME 2019 13th International Conference on Energy and Sustainability ES2019, July 15-17, 2019, Bellevue, WA, USA.
[66] Kenzo Repole, "The Development and Application of Design and Optimization Methods for Energy Intensive Mechanical Systems for Challenging Environments as Applied to a Concentrated Solar Power Particle Lift System, " Ph.D Thesis, retrieved from smartech.gatech.edu/bitstream/handle/1853/61233/REPOLE-DISSERTATION-2019.pdf
[67] Clifford K. Ho, Jesus D. Ortega, Peter Vorobieff, Gowtham Mohan, Andrew Glen, Andres L. Sanchez, Darielle Dexheimer, Nathan Schroeder, and Vanderlei Martins, "Characterization of Particle and Heat Losses from a High-Temperature Particle Receiver, Proceedings of the ASME 2019 13th International Conference on Energy Sustainability ES2019, Paper ES2019-382 , July 15-17, 2019, Bellevue, WA, USA.

Technical Areas of Interest

Gen3 CSP component development and scaleup:As discussed above, significant development of components for a Gen3 particle based sCO_2 power plant are still required to meet LCOE goals and validate maturity and reliability for commercial applications. For this Topic area preference will be given to those applications in **SOLAR Tiers 2 or 3,** to be ready for installation in appropriate test facilities or demonstration plants. Tier 1 proposals may be accepted where novel material systems are involved for component development requiring higher temperature capability (beyond 750°C) and specific applications. This topic area encourages specific component-level research opportunities that will include:

Receiver System (focusing on receiver and particle lifts)*:* CFD analysis of present-day open aperture receivers[68] have shown the impact of wind speed and direction upon receiver efficiency. Validation of CFD analyses will likely require testing of receiver prototypes at a SOLAR Tier 3 scale, closer to expected commercial conditions.

Tubular enclosed receivers are important and may be used to heat fluidized suspensions of particles for power and process heating applications. In addition, they can also be used to supply heat to reactants for endothermic reactions. Since the tube walls are limited by the allowable temperatures of the alloy, the outlet temperature of gases and suspensions is limited to 750 °C; novel materials like ceramic and cermet composites may enable temperatures exceeding 800 °C, for applications that require higher temperatures.

For receiver systems, design targets and test conditions are summarized respectively in Table 3, to demonstrate a receiver consistent with SETO's targets. Table 4 defines a Tier 3 test capability of a multi-m^2 aperture receiver with a lift system for elevating particles. An ability to cool the hot particles and cycle the particles for steady-state operation is required.

Table 3: Receiver system design targets at scale (aperture area >5-10 m^2)

System Design Targets	Efficiency	Cost	Losses
Receiver	≥80-85% annualized thermal efficiency; particle inlet temperatures = 200-600°C; outlet temperatures= 600-1,000°C	≤60 $\$/kW_{th}$	<0.1% annualized particle mass loss
Lift	≥83-85%	≤30 $\$/kW_{th}$	<0.1% heat loss
Tower	-	<30 $\$/kW_{th}$	NA
Complete receiver system, INSTALLED	-	<$120/ kW_{th}	NA

[68] Brantley Mills, Reid Shaeffer, Lindsey Yue, and Clifford K. Ho, "improving next-generation falling particle receiver designs subject to anticipated operating conditions," ES2020-12356, Proceedings of the ASME 2020 14th International Conference on Energy Sustainability, ES2020, June 8-10, 2020, Denver, CO, USA.

Table 4: Targets for Tier 3 scale testing of >5-10 m2 particle receiver

Parameter	Value	Units
Receiver aperture size	5<Area<100	m^2
Direct Normal Incidence (DNI)	150-1,000	W/m^2
Concentration Ratio	350-2,000	-
Wind velocity and direction	By local climate	-
Annualized receiver efficiency	≥83%	-
Maximum particle receiver exit temperature	~1,000	C
Maximum ΔT	>600	C
Cumulative time on testing	>500	hours
Continuous time on testing	>5 hours for > 10 days	-
Cost (for tower + receiver + skip hoist) at commercial scale	< 120	$/kWt

As discussed above, particle lift designs have considerable cost uncertainty and current prototype designs are likely to exceed the required budget to achieve SETO's cost target. Considering that the skip, hoist, rope and variable-frequency drive (VFD) are the principal cost contributions (outside the steel rails), cost reduction and design of **the primary and intermediate hoist systems** are of interest, consistent with costs below 30 $/kWt as summarized in Table 3.

***Particle Heat Exchangers*:** Particle heat exchangers have currently been developed at the 1 MW_{th} scale in the Gen3 CSP system using a moving packed bed PCHE design. These designs typically use nickel alloys for large surface areas, leading to high costs. Additionally, pathways for scaling up designs remain unclear for typical commercial sizes of approximately 200 MW_{th}. New heat exchanger designs are required for duties greater than 1 MW_{th}, at a cost target of less than 300 $/$MW_e$, with a stretch goal of 200 $/$MW_e$ (100 $/$MW_{th}$). Opportunities for development include moving-bed heat exchangers made from low-cost materials capable of temperatures above 800°C, fluidized-bed heat exchangers at multi MW_{th} scale, moving-bed shell-and tube heat exchangers, and novel air-cooled high temperature heat exchanger designs. The design and Tier 3 testing targets are listed in Table 5.

Table 5: Tier 3 Development and Testing Requirements of Particle-sCO2 Heat Exchangers

Thermal Duty	1≤Q≤5		MW
Heat Exchanger "U"	≥300		$W/m^2.°K$
Design Temperature	850-1,000		°C
Approach Temperature	15	50	°C
Hot solids Inlet Temperature	850-1000	850-1000	°C
sCO2 Outlet Temperature	≥700	≥700	°C
Cold Solids Outlet Temperature	200-600	200-600	°C
sCO2 Inlet Temperature	185-585	150-550	°C

$\dot{M}$solids	1.5-8	2-10	kg/s
Cost target for scaled up heat exchanger ($/UA)	<10	<10	$/(W/K)
Cumulative Testing requirement	>100	>100	hours

Particle CSP Towers: Molten salt receivers are heavy due to the need for outlet headers, salt in the receiver, and reflood systems in case of loss of fluid. In contrast to these molten salt receivers, particle receivers do not need to be designed with the weight of heat transfer material on top of the tower. However, since the particle lift is located inside the tower, the weight of the lift support must be accounted for. In addition, the tower is likely to be taller compared to a molten salt tower, which allows the use of multiple receivers to face multiple parts of the field. The CSP tower technology can thus make use of structural experience gained in the wind turbine industry (recognizing that the receiver weight may be up to an order of magnitude heavier than wind turbine hubs and nacelles) and may be able to make use of concrete and concrete-steel hybrids for heights over 150 m, and manufacturing advancements. For varying particle tower designs for 5, 50, and 100 MW_e particle towers (to 70, 185 and 293 m heights), design advances and a cost reduction to 30 $/$kW_{th}$ (as in Table 4) are sought.

Solid particle media: The particles used in the Gen3 system receiver cost nearly $1000/tonne and are responsible for a majority of the TES costs. Although alternate materials have been explored, such as silica sand or bauxite particles, research on the use of alternate particles remains in its early stages. Table 6, below, lists the attributes for particles sought for future CSP applications. Development, testing and characterization of particles are of interest.

Table 6: Targets and needs for particles for receivers, TES, and heat exchangers

Range	Desired value	Target	Reference
Receiver Design Efficiency			
Absorptivity	0.55-0.93	Maximize	[69]
Emissivity	0.72-0.88	Minimize	[65]
Particle size	200-1000 µm; ≤ 100 µm for fluidized bed receivers		[70]
Sphericity	0.9	Maximize	-
Roundness	0.9	Reduce	-
HEX Efficiency			
Particle size	160-500 µm	Minimize	[71]

[69] Ho C, Christian J, Gill D, et al. Technology advancements for next generation falling particle receivers. Energy Procedia. 2014;49: 398-407. https://doi.org/10.1016/j.egypro.2014.03.043

[70] Tan T, Chen Y. Review of study on solid particle solar receivers. Renew Sustain Energy Rev. 2010;14:265-276. https://doi.org/10.1016/j.rser.2009.05.012.

[71] Kevin J. Albrecht, Clifford K. Ho, "Design and operating considerations for a shell-and-plate, moving packed bed, particle-to-sCO2 heat exchanger," Solar Energy. Volume 178, 15 January 2019, Pages 331-340, https://doi.org/10.1016/j.solener.2018.11.065

Thermal conductivity	0.5-2	Maximize	[72]
Cost	10-170 $/tonne	Reduce	[73]
Other requirements: size uniformity, low agglomeration, low erosion rates, are particle-specific			

Particle-heated steam generation systems: Beyond sCO_2 power cycles, particle receivers and TES can potentially be used for steam-Rankine power cycles, or as heat input for industrial process steam generation.

Previous SETO efforts on solid particle systems for CSP have focused on integration with sCO_2 power cycles, due to the high efficiency of such systems, consistent with SETO's 2030 target. However, there may be near-term opportunities to rapidly integrate solar-heated particle systems with existing steam-based generators. Also of interest are innovative concepts for particle-based receivers, TES, or steam generating systems that can supply heat at 550 °C or above, which can show significant cost improvements relative to incumbent molten nitrate salt-based towers.

As steam remains a common heat transfer fluid for industrial processes, particle-based steam generators for industrial heating are needed to ensure the broad applicability of this technology. Consistent with the goals of the DOE Hydrogen Shot Initiative,[74] a potentially promising application for steam is as an input to high temperature solid oxide electrolysis cells (SOECs) for hydrogen generation. However, significant uncertainty exists as to the optimal configurations for integrating CSP technologies to provide heat for cost-effective SOEC systems. Steam generation for hydrogen production will likely tolerate much smaller CSP plants than today's systems for power production – on the order of a 12 MW_{th} tower for 50,000 kg H_2/day. There is an unmet opportunity to produce validated costs and design for a small (10-12 MWt) particle tower with 800 °C particles feeding steam to a SOEC through TES and recuperators. As such, the focus of this Technical Area is the design and testing of **CSP components** for a ~10 MW_{th} particle tower with TES, integrated via innovative steam generators for 5 bar/800 °C steam feeding a SOEC of ~75 MW_e capacity. From the CSP perspective, careful consideration of the TES system to enable round-the-clock hydrogen generation is necessary.

Particle technologies for steam generation for other high-temperature industrial processes is also of interest in this topic. ***Low(<3.5 barg/150°C) and medium-pressure/temperature (40 barg/250°C) steam applications are not of interest***. Applicants should clearly justify why the performance characteristics of their proposed designs are relevant to a highly impactful segment of the industrial process heating market. Proposals for particle-based heating concepts for specific industrial processes, more specific than steam, should apply to Topic 1.

[72] Ma Z, Glatzmaier GC, Mehos M. Development of solid particle thermal energy storage for concentrating solar power plants that use fluidized bed technology. Energy Procedia. 2014;49:898-907.
[73] Fernández P, Miller FJ. Performance analysis and preliminary design optimization of a small particle heat exchange receiver for solar tower power plants. Sol Energy. 2015;112:458-468. https://doi.org/10.1016/j.solener.2014.11.012
[74] https://www.energy.gov/eere/fuelcells/hydrogen-shot

Improved sCO_2 power blocks for integration with particle based CSP: The DOE is currently supporting the demonstration of sCO_2 power block testing at two scales: SETO's 'TESTBED' program,[75] a 5 MW_e system with a turbine inlet temperature of 550 °C, and the Office of Fossil Energy's STEP Facility,[76] a 10 MW_e pilot with a turbine inlet temperature of 700 °C scale. Both power blocks use recompression Brayton cycles that limit ΔT to 150-175 °C, which creates significant challenges for integration with CSP and TES. Alternate cycle design features (such as high temperature recuperator bypass, cascaded cycles, or precompression cycles) enabled by the wide operating temperature of solid particles may present opportunities to significantly reduce the cost of CSP with sCO_2 power cycles. This may also enable new or lower cost component development for turbomachinery and recuperators.

Broadening the temperature range of sCO_2 cycle operation is likely to reduce efficiency; however, the reduction in power block efficiency may be acceptable if cost reductions can be achieved**.** For example, a power block cost of \$700/kW_e can be attained using a \$200/kW_e primary heat exchanger and \$500/kW_e for the remainder of the power block. This system can potentially coexist with a 45% efficiency cycle and still attain SETO's LCOE target.

All work under EERE funding agreements must be performed in the United States unless a waiver for foreign work is submitted by the recipient/applicant and approved by DOE. 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).
- The development of the core SOEC technology.
- Proposals that couple mature solar thermal collectors for supplying process steam (< 40 bars/250 C), with no additional innovation.
- Low(<3.5 barg/150°C) and medium-pressure/temperature (40 barg/250°C) steam applications.

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.

[75] https://www.energy.gov/eere/solar/seto-2020-integrated-testbed
[76] https://netl.doe.gov/coal/sco2/step10pilotplant

II. Award Information

A. Award Overview

i. Estimated Funding

EERE expects to make a total of approximately $25,000,000 of federal funding available for new awards under this FOA, subject to the availability of appropriated funds. EERE anticipates making approximately 8 to 15 awards under this FOA. EERE may issue one, multiple, or no awards. Individual awards may vary between $750,000 and $6,000,000.

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	Concentrating Solar Thermal for Industrial Decarbonization	4-8	$750,000	$6,000,000	$15,000,000	12-36
2	Concentrating Solar-thermal Particle Technologies for Generation 3 CSP and Beyond (Gen3++)	4-7	$750,000	$6,000,000	$10,000,000	12-36

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 months up to 36 months in length, comprised of 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.xiv. 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	Concentrating Solar Thermal for Industrial Decarbonization	12-36
2	Concentrating Solar-thermal Particle Technologies for Generation 3 CSP and Beyond (Gen3++)	12-36

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.

DOE/NNSA FFRDCs are eligible to apply for funding as a (1) 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.

iii. Foreign Entities

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding under this FOA. Other than as provided in the "Individuals" or "Domestic Entities" sections above, all prime recipients receiving funding under this FOA must be incorporated (or otherwise formed) under the laws of a state or territory of the United States and have a physical

location for business operations in the United States. If a foreign entity applies for funding as a prime recipient, it must designate in the Full Application a subsidiary or affiliate incorporated (or otherwise formed) under the laws of a state or territory of the United States to be the prime recipient. The Full Application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate.

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

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

A foreign entity may receive funding as a subrecipient.

iv. Incorporated Consortia

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

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

v. Unincorporated Consortia

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

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

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

B. Cost Sharing

The cost share must be at least 20% of the total allowable costs 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.)

The cost share must be at least 50% of the total allowable costs for demonstration 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.)

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.

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 volunteer time or 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); or
- Expenditures that were reimbursed under a separate federal program.

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

Cost share contributions must be specified in the project budget, verifiable from the prime recipient's records, and necessary and reasonable for proper and efficient accomplishment of the project. As all sources of cost share are considered part of total project cost, the cost share dollars will be scrutinized under the same federal regulations as federal dollars to the project. Every cost share contribution must be reviewed and approved in advance by the Contracting Officer and incorporated into the project budget before the expenditures are incurred.

Applicants are encouraged to refer to 2 CFR 200.306 as amended by 2 CFR 910.130 for additional 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

Must meet all compliance criteria listed below or they will be considered noncompliant. EERE will not review or consider noncompliant submissions, including 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.

vii. Compliance Criteria

***i.* Concept Papers (required for all Topic Areas)**

Concept Papers are deemed compliant if:

- The Concept Paper complies with the content and form requirements in Section IV.C. 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.

***ii.* Full Applications**

Full Applications are deemed compliant if:

- The applicant submitted a compliant Concept Paper;
- The Full Application 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 the FOA.

***iii.* Replies to Reviewer Comments**

Replies to Reviewer Comments are deemed compliant if:

- The Reply to Reviewer Comments complies with the content and form requirements in Section IV.E. 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.

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

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.

G. Questions Regarding Eligibility

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

IV. Application and Submission Information

A. Application Process

The application process will include two phases: Concept Paper phase, and a Full Application phase. **Only applicants who have submitted an eligible Concept Paper will be eligible to submit a Full Application**.

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

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

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

- Each must be submitted in Adobe PDF format unless stated otherwise;
- Each must be written in English;
- All pages must be formatted to fit on 8.5 x 11 inch paper with margins not less than one inch on every side. Use 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 Concept Papers, Full Applications, and Replies to Reviewer Comments at least 48 hours in advance of the submission deadline**. Under normal conditions (i.e., at least 48 hours in advance of the submission deadline), applicants should allow at least 1 hour to submit a Concept Paper, Full Application, or Reply to Reviewer Comments. Once the 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 Concept Paper, Full Application, or Reply to Reviewer Comments before the applicable deadline.

EERE urges applicants to carefully review their 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 Forms

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

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

TechnicalVolume_Part_1
TechnicalVolume_Part_2

C. Content and Form of the Concept Paper

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

i. Concept Paper Content Requirements

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

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

The Concept Paper must conform to the following content requirements:

Section	Page Limit	Description
Cover Page	1 page maximum	The cover page should include the project title, the specific 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	4 pages maximum	Applicants are required to describe succinctly: • The proposed technology, including its basic operating principles and how it is unique and innovative; • The proposed technology's target level of performance (applicants should provide technical data or other support to show how the proposed target could be met); • The current state-of-the-art in the relevant field and application, including key shortcomings, limitations, and challenges; • How the proposed technology will overcome the shortcomings, limitations, and challenges in the relevant field and application; • The potential impact that the proposed project would have on the relevant field and application; • The key technical risks/issues associated with the proposed technology development plan; and • The impact that EERE funding would have on the proposed project.
Addendum	1 page maximum	Applicants are required to describe succinctly the qualifications, experience, and capabilities of the proposed Project Team, including: • Whether the Principal Investigator (PI) and Project Team have the skill and expertise needed to successfully execute the project plan; • Whether the applicant has prior experience which demonstrates an ability to perform tasks of similar risk and complexity; • Whether the applicant has worked together with its teaming partners on prior projects or programs; and • Whether the applicant has adequate access to equipment and facilities necessary to accomplish the effort and/or clearly explain how it intends to obtain access to the necessary equipment and facilities. • Applicants may provide graphs, charts, or other data to supplement their Technology Description.
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.

D. 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 clicking the "Create Concept Paper" button 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:

Component	File Format	Page Limit	File Name
Technical Volume	PDF	15	ControlNumber_LeadOrganization_TechnicalVolume
Resumes	PDF	2 pages each	ControlNumber_LeadOrganization_Resumes
Letters of Commitment	PDF	1 page each	ControlNumber_LeadOrganization_LOCs
SF-424	PDF		ControlNumber_LeadOrganization_App424
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	PDF		ControlNumber_LeadOrganization_SF-LLL
Foreign Entity and Foreign Work Waivers	PDF		ControlNumber_LeadOrganization_Waiver
Diversity Equity and Inclusion Plan	PDF	5	ControlNumber_LeadOrganization_DEIP
Current and Pending Support	PDF	n/a	ControlNumber_LeadOrganization_CPS

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 15 pages, including the cover page, table of contents, and all citations, charts, graphs, maps, photos, or other graphics, and must include all of the information in the table below. The applicant should consider the weighting of each of the evaluation criteria (see Section V.A.ii of the FOA) when preparing the Technical Volume.

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

SECTION/PAGE LIMIT	DESCRIPTION

Cover Page (1)	The cover page should include
	• The project title,
	• The specific FOA Topic Area being addressed (if applicable) and Project Focus Areas
	• 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.

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.
Summary Statement of Project Objectives (Approximately 40% of the Technical Volume)	Provide a succinct description of the specific activities to be conducted over the proposed period of performance. Descriptions should contain enough detail to convey and disclose the work occurring. (Vague statements such as "We will then complete a proprietary process" are unacceptable.) A summary of the general work involved is helpful for the review process, however, spending a tremendous amount of time outlining every detail of the project is not warranted until after selection. It is the applicant's responsibility to prepare an adequately detailed Summary SOPO to convince reviewers that the proposed project and team can meet the goals of the funding program. The Summary SOPO should contain the following information:

	• Scope Summary: The applicant should provide a summary description of the overall work scope and approach to achieving the projectobjectives/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. **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) **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:
	  ○ The roles and the work to be performed by each PI and Key Participant;
	  ○ Business agreements between the applicant and each PI and Key Participant;
	  ○ How the various efforts will be integrated and managed;
	  ○ Process for making decisions on scientific/technical direction;
	  ○ Publication arrangements;
	  ○ Intellectual Property issues; and
	  ○ Communication plans

Appendices	• Applicants should attach letters of commitment from all Subrecipient/third party cost share providers as an appendix. Letters of commitment do not count towards the page limit. • Applicants may attach one-page letters of support from other relevant entities (i.e. end users of the proposed solution) as an appendix. Letters of support do not count towards the page limit. Multi-page letters of support are not allowed and will not be reviewed. • Applicants may attach one or two-page resumes for key participating team members as an appendix. Resumes do not count towards the page limit. Resumes over 2 pages are not allowed and will not be reviewed. Note: Footnotes and endnotes are counted toward the maximum page requirement. Applicants may not include a list of references as an appendix.

	References and outside links to additional content may be considered by reviewers, however, applications should not require references or outside content to be understood and reviewed.

iii. Resumes

Applicants are required to submit one-page resumes for key participating team members. Multi-page resumes are not allowed.

A resume provides information that can be used by reviewers to evaluate the individual's skills, experience, and potential for leadership within the scientific community. Applicants are required to submit two-page resumes for the Principal Investigator and all Senior/Key Personnel that include the following:

1. Contact Information;
2. Education and training: Provide institution, major/area, degree, and year for undergraduate, graduate, and postdoctoral training;
3. Research and Professional Experience: Beginning with the current position, list professional/academic positions in chronological order with a brief description. List all current academic, professional, or institutional appointments, foreign or domestic, at the applicant institution or elsewhere, whether or not remuneration is received, and, whether full-time, part-time, or voluntary;
4. Awards and honors;
5. A list of up to 10 publications most closely related to the proposed project. For each publication, identify the names of all authors (in the same sequence in which they appear in the publication), the article title, book or journal title, volume number, page numbers, year of publication, and website address if available electronically. Patents, copyrights, and software systems developed may be provided in addition to or substituted for publications. An abbreviated style such as the Physical Review Letters (PRL) convention for citations (list only the first author) may be used for publications with more than 10 authors; and
6. Synergistic Activities: List up to five professional and scholarly activities related to the proposed effort.

Save the resumes in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_Resumes".

In future FOAs, EERE may require a biographical sketch for the PI and senior/key personnel. In the meantime, in lieu of a resume, it is acceptable to use the biographical sketch format approved by the National Science Foundation (NSF). The biographical sketch format 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://nsf.gov/bfa/dias/policy/nsfapprovedformats/biosketch.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.

iv. Letters of Commitment

Submit letters of commitment from all subrecipient and third party cost share providers. If applicable, also include any letters of commitment from partners/end users (one-page maximum per letter). Save the letters of commitment in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_LOCs".

v. 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".

vi. Budget Justification Workbook

Applicants are required to complete the Budget Justification Workbook. This form is available on EERE Exchange at https://eere-Exchange.energy.gov/. Prime recipients must complete each tab of the Budget Justification Workbook for the project as a whole, including all work to be performed by the prime recipient and its subrecipients and contractors. Applicants should include costs associated with required annual audits and incurred cost proposals in their proposed budget documents. The "Instructions and Summary" included with the Budget Justification Workbook will auto-populate as the applicant enters information into the Workbook. Applicants must carefully read the "Instructions and Summary" tab provided within the Budget Justification Workbook. Save the Budget Justification Workbook in a single Microsoft Excel file using the following convention for the title "ControlNumber_LeadOrganization_Budget_Justification".

vii. 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".

viii. 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 senior/key personnel 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".

ix. 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".

x. 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".

xi. 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".

xii. 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".

xiii. Waiver Requests: Foreign Entity 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".

xiv. U.S. Manufacturing Commitments

A primary objective of DOE's multi-billion dollar research, development and demonstration investments is to cultivate new research and development ecosystems, manufacturing capabilities, and supply chains for and by U.S. industry and labor. Therefore, in exchange for receiving taxpayer dollars to support an applicant's project, the applicant must agree to the following U.S. Competitiveness Provision as part of an award under this FOA.

U.S. Competitiveness

The Recipient agrees 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 Recipient can show to the satisfaction of DOE that it is not commercially feasible. In the event DOE agrees to foreign manufacture, there will be a requirement that the Government's support of the technology be recognized in some appropriate manner, e.g., alternative binding commitments to provide an overall net benefit to the U.S. economy. The Recipient agrees that it will not license, assign or otherwise transfer any subject invention to any entity, at any tier, unless that entity agrees to these same requirements. Should the Recipient or other such entity receiving rights in the invention(s): (1) undergo a change in ownership amounting to a controlling interest, or (2) sell, assign, or otherwise transfer title or exclusive rights in the invention(s), then the assignment, license, or other transfer of rights in the subject invention(s) is/are suspended until approved in writing by DOE. The Recipient and any successor assignee will convey to DOE, upon written request from DOE, title to any subject invention, upon a breach of this paragraph. The Recipient will include this paragraph in all subawards/contracts, regardless of tier, for experimental, developmental or research work.

A subject invention is any invention conceived or first actually reduced in performance of work under an award. An invention is any invention or discovery which is or may be patentable.

As noted in the U.S. Competitiveness Provision, at any time in which an entity cannot meet the requirements of the U.S. Competitiveness Provision, the entity may request a modification or waiver of the U.S. Competitiveness Provision. For example, the entity may propose modifying the language of the U.S. Competitiveness Provision in order to change the scope of the requirements or to provide more specifics on the application of the requirements for a particular technology. As another example, the entity may request that the U.S. Competitiveness Provision be waived in lieu of a net benefits statement or U.S. manufacturing plan. The statement or plan would contain specific and enforceable commitments that would be beneficial to the U.S. economy and competitiveness. Commitments could include manufacturing specific products in the U.S., making a specific investment in a new or existing U.S. manufacturing facility, keeping certain activities based in the U.S. or supporting a certain number of jobs in the U.S. related to the technology. If DOE, in its sole discretion, determines that the proposed modification or waiver promotes commercialization and provides substantial U.S. economic benefits, DOE may grant the request and, if granted, modify the award terms and conditions for the requesting entity accordingly.

The U.S. Competitiveness Provision is implemented by DOE pursuant to a Determination of Exceptional Circumstances (DEC) under the Bayh-Dole Act and DOE Patent Waivers. See Section VIII.J. Title to Subject Inventions of this FOA for more information on the DEC and DOE Patent Waivers.

xv. Data Management Plan (DMP)

Each applicant whose Full Application is selected for award negotiations will be required to submit a data management plan (DMP) during the award negotiations phase. A DMP explains how, when appropriate, data generated in the course of the work performed under an EERE award will be shared and preserved in order to validate the results of the proposed work or how the results could be validated if the data is not shared or preserved. The DMP must provide a plan for making all research data displayed in publications resulting from the proposed work digitally accessible at the time of publications.

xvi. Diversity, Equity and Inclusion Plan

As part of the application, 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 that describes the actions the applicant will take to foster a welcoming and inclusive environment, support people from groups underrepresented 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 underserved communities (also see Section I.A.iii). The plan should include SMART milestone per Budget Period supported by metrics to measure the success of the proposed actions, and will be incorporated into the award if selected. The Diversity, Equity, and Inclusion Plan should contain the following information:

- Equity Impacts: the impacts of the proposed project on underserved communities, including social and environmental impacts.
- Benefits: The overall benefits of the proposed project, if funded, to underserved communities; and
- How diversity, equity, and inclusion objectives will be incorporated in the project.

The following is a non-exhaustive list of actions that can serve as examples of ways the proposed project could incorporate diversity, equity, and inclusion elements. These examples should not be considered either comprehensive or prescriptive. Applicants may include appropriate actions not covered by these examples.

a. Include persons from groups underrepresented in STEM as PI, co-PI, and/or other senior personnel;
b. Include persons from groups underrepresented in STEM as student researchers or post-doctoral researchers;
c. Include faculty or students from Minority Serving Institutions as PI/co-PI, senior personnel, and/or student researchers, as applicable;
d. Enhance or collaborate with existing diversity programs at your home organization and/or nearby organizations;
e. Collaborate with students, researchers, and staff in Minority Serving Institutions;

f. Disseminate results of research and development in Minority Serving Institutions or other appropriate institutions serving underserved communities;
g. Implement evidence-based, diversity-focused education programs (such as implicit bias training for staff) in your organization;
h. Identify Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses and Veteran Owned Businesses to solicit as vendors and sub-contractors for bids on supplies, services and equipment.

The Diversity, Equity, and Inclusion Plan must not exceed 5 pages. Save the Diversity, Equity and Inclusion Plan in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_DEIP".

xvii. Current and Pending 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. As part of the application, the principal investigator and senior/key personnel at the applicant 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.

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.

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.

PIs and senior/key personnel must provide a separate disclosure statement listing the required information above regarding current and pending support. Each individual must sign and date their respective disclosure statement and include the following certification statement:

> I, [Full Name and Title], certify to the best of my knowledge and belief that the information contained in this Current and Pending Support Disclosure Statement is true, complete and accurate. I understand that any false, fictitious, or fraudulent information, misrepresentations, half-truths, or omissions of any material fact, may subject me to criminal, civil or administrative penalties for fraud, false statements, false claims or otherwise. (18 U.S.C. §§ 1001 and 287, and 31 U.S.C. 3729-3730 and 3801-3812). I further understand and agree that (1) the statements and representations made herein are material to DOE's funding decision, and (2) I have a responsibility to update the disclosures during the period of performance of the award should circumstances change which impact the responses provided above.

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. If the NSF format is used, the individual must still include a signature, date, and a certification statement using the language included in the paragraph above.

Save the Current and Pending Support in a single PDF file using the following convention for the title "ControlNumber_LeadOrganization_CPS".

E. Content and Form of Replies to Reviewer Comments

If replies to reviewer comments are applicable, EERE will provide applicants with reviewer comments following the 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.

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.

F. Post Selection Information Requests

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

- Personnel proposed to work on the projectand collaborating organizations (See Section VI.B.xviii. Participants and Collaborating Organizations);
- Current and Pending Support (See Sections IV.E.xvii and VI.B.xix. Current and Pending Support);
- An Intellectual Property Management Plan (if applicable) describing how the project team/consortia members will handle intellectual property rights and issues between themselves while ensuring compliance with federal intellectual property laws, regulations, and policies in accordance with VI.B.x Intellectual Property Management Plan;
- A Data Management Plan (if applicable) describing how all research data displayed in publications resulting from the proposed work will be digitally accessible at the time of publications, in accordance with Section VI.B.xxi.;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.

G. Dun and Bradstreet Universal Numbering System (DUNS), Unique Entity Identifier (UEI), 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 number (until April 4, 2022) and UEI 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. Please note: A DUNS number will no longer be required after April 3, 2022. After that date, applicants will be required to provide ONLY a UEI. DOE may not make a federal award to an applicant until the applicant has complied with all applicable DUNS, UEI, 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.

H. 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.

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. All sub-criteria are of equal weight.

Criterion 1: Technical Merit, Innovation, and Impact (45%)
This criterion involves consideration of the following factors:
Technical Merit and Innovation

- Extent to which the proposed technology or process is innovative;

- Degree to which the current state of the technology and the proposed advancement are clearly described;
- Extent to which the application specifically and convincingly demonstrates how the applicant will move the state-of-the-art to the proposed advancement; and
- Sufficiency of technical detail in the application to assess whether the proposed work is scientifically meritorious and revolutionary, including relevant data, calculations and discussion of prior work in the literature with analyses that support the viability of the proposed work.

Impact of Technology Advancement

- How the project supports the topic area objectives and target specifications and metrics; and
- The potential impact of the project on advancing the state-of-the-art.

Criterion 2: Quality and Likelyhood of Completion of Stated Goals (30%)

This criterion involves consideration of the following factors:

Research Approach, Workplan and SOPO

- Degree to which the approach and critical path have been clearly described and thoughtfully considered; and
- Degree to which the task descriptions are clear, detailed, timely, and reasonable, resulting in a high likelihood that the proposed Workplan and SOPO will succeed in meeting the project goals.

Identification of Technical Risks

- Discussion and demonstrated understanding of the key technical risk areas involved in the proposed work and the quality of the mitigation strategies to address them.

Baseline, Metrics, and Deliverables

- The level of clarity in the definition of the baseline, metrics, and milestones; and
- Relative to a clearly defined experimental baseline, the strength of the quantifiable metrics, milestones, and a mid-point deliverables defined in the application, such that meaningful interim progress will be made.

Market Transformation Plan

- Identification of target market, competitors, and distribution channels for proposed technology along with known or perceived barriers to market penetration, including mitigation plan; and
- Comprehensiveness of market transformation plan including but not limited to product development and/or service plan, commercialization timeline, financing, product marketing, legal/regulatory considerations including intellectual property, infrastructure requirements, , and product distribution.

Criterion 3: Capability and Resources of the Applicant/Project Team (15%)

This criterion involves consideration of the following factors:

- The capability of the Principal Investigator(s) and the proposed team to address all aspects of the proposed work with a high probability of success. The qualifications, relevant expertise, and time commitment of the individuals on the team;

- The sufficiency of the facilities to support the work;
- The degree to which the proposed consortia/team demonstrates the ability to facilitate and expedite further development and commercial deployment of the proposed technologies;
- The level of participation by project participants as evidenced by letter(s) of commitment and how well they are integrated into the Workplan; and
- The reasonableness of the budget and spend plan for the proposed project and objectives.

Criterion 4: Diversity, Equity, and Inclusion (10%)
This criterion involves consideration of the following factors:

- The quality and manner in which the measures incorporate diversity, equity and inclusion goals in the project; and

Extent to which the project benefits underserved communities.

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:

- 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; and

- The degree to which the proposed project, or group of projects, represent a desired geographic distribution (considering past awards and current applications);
- The degree to which the proposed project exhibits technological or programmatic diversity when compared to the existing DOE project portfolio and other projects selected from the subject FOA;

Diversity (other than technological)

- The degree to which the proposed project incorporates diversity, equity, and inclusion elements, including but not limited to team members from Minority Serving Institutions (e.g. Historically Black Colleges and Universities (HBCUs)/Other Minority Institutions), Minority Business Enterprises, Minority Owned Businesses, Woman Owned Businesses, Veteran Owned Businesses, or members within underserved communities.

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.

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.

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 200.206.

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. **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.

3. **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.

4. **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 Concept Papers, and Full Applications will not be accepted through Grants.gov.

5. **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.

6. **Interim Conflict of Interest Policy for Financial Assistance**
The DOE interim Conflict of Interest Policy for Financial Assistance (COI Policy) can be found at: PF 2022-17 Department of Energy Interim Conflict of Interest Policy Requirements for Financial Assistance | Department of Energy. This policy is applicable to all non-Federal entities applying for, or that receive, DOE funding by means of a financial assistance award (e.g., a grant, cooperative agreement, or technology investment agreement) and, through the implementation of this policy by the entity, to each Investigator who is planning to participate in, or is participating in, the project funded wholly or in part under the DOE financial assistance award. DOE's interim COI Policy establishes standards that provide a reasonable expectation that the design, conduct, and reporting of projects funded wholly or in part under DOE financial assistance awards will be free from bias resulting from financial conflicts of interest or organizational conflicts of interest. The applicant is subject to the requirements of the interim COI Policy and within each application for financial assistance, the applicant must certify that it is, or will be by the time of receiving any financial assistance award, compliant with all requirements in the interim COI Policy. The applicant must flow down the requirements of the interim COI Policy to any subrecipient non-Federal entities.

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. Participants and Collaborating Organizations

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 and a list of collaborating organizations within 30 days after the applicant is notified of the selection. 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 collaborating organizations, and submit updated information during the life of the award.

xviii. Current and Pending Support

If selected for award negotiations, within 30 days of the selection notice, the selectee must submit 1) current and pending support disclosures and resumes for any new PIs or senior/key personnel and 2) updated disclosures if there have been any changes to the current and pending support submitted with the application. Throughout the life of the award, the Recipient has an ongoing responsibility to submit 1) current and pending support disclosure statements and resumes for any new PI and senior/key personnel and 2) updated

disclosures if there are changes to the current and pending support previously submitted to DOE. Also See. Section IV.E.xvii.

xix. U.S. Manufacturing Commitments

A primary objective of DOE's multi-billion dollar research, development and demonstration investments is to cultivate new research and development ecosystems, manufacturing capabilities, and supply chains for and by U.S. industry and labor. Therefore, in exchange for receiving taxpayer dollars to support an applicant's project, the applicant must agree to the following U.S. Competitiveness Provision as part of an award under this FOA.

U.S. Competitiveness

> The Recipient agrees 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 Recipient can show to the satisfaction of DOE that it is not commercially feasible. In the event DOE agrees to foreign manufacture, there will be a requirement that the Government's support of the technology be recognized in some appropriate manner, e.g., alternative binding commitments to provide an overall net benefit to the U.S. economy. The Recipient agrees that it will not license, assign or otherwise transfer any subject invention to any entity, at any tier, unless that entity agrees to these same requirements. Should the Recipient or other such entity receiving rights in the invention(s): (1) undergo a change in ownership amounting to a controlling interest, or (2) sell, assign, or otherwise transfer title or exclusive rights in the invention(s), then the assignment, license, or other transfer of rights in the subject invention(s) is/are suspended until approved in writing by DOE. The Recipient and any successor assignee will convey to DOE, upon written request from DOE, title to any subject invention, upon a breach of this paragraph. The Recipient will include this paragraph in all subawards/contracts, regardless of tier, for experimental, developmental or research work.

A subject invention is any invention conceived or first actually reduced in performance of work under an award. An invention is any invention or discovery which is or may be patentable.

As noted in the U.S. Competitiveness Provision, at any time in which an entity cannot meet the requirements of the U.S. Competitiveness Provision, the entity may request a modification or waiver of the U.S. Competitiveness Provision. For example, the entity may propose modifying the language of the U.S. Competitiveness Provision in order to change the scope of the requirements or to provide more specifics on the application of the requirements for a particular technology. As another example, the entity may request that the U.S. Competitiveness Provision be waived in lieu of a net benefits statement or U.S. manufacturing plan. The statement or plan would contain specific and enforceable

commitments that would be beneficial to the U.S. economy and competitiveness. Commitments could include manufacturing specific products in the U.S., making a specific investment in a new or existing U.S. manufacturing facility, keeping certain activities based in the U.S. or supporting a certain number of jobs in the U.S. related to the technology. If DOE, in its sole discretion, determines that the proposed modification or waiver promotes commercialization and provides substantial U.S. economic benefits, DOE may grant the request and, if granted, modify the award terms and conditions for the requesting entity accordingly.

The U.S. Competitiveness Provision is implemented by DOE pursuant to a Determination of Exceptional Circumstances (DEC) under the Bayh-Dole Act and DOE Patent Waivers. See Section VIII.J. Title to Subject Inventions of this FOA for more information on the DEC and DOE Patent Waivers.

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: *cspfoa22@ee.doe.gov*. Questions must be submitted not later than 3 business days prior to the application due date and time. Please note, feedback on individual concepts will not be provided through Q&A.

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

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

VIII. Other Information

A. FOA Modifications

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

B. Government Right to Reject or Negotiate

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

C. Commitment of Public Funds

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

D. Treatment of Application Information

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

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

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

The cover sheet of the Concept Paper, Full Application, Reply to Reviewer Comments 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 Concept Papers, Full Applications, and Replies to Reviewer Comments and other submissions. No submissions will be returned. By applying to EERE for funding, applicants consent to EERE's retention of their submissions.

J. Title to Subject Inventions

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

- Domestic Small Businesses, Educational Institutions, and Nonprofits: Under the Bayh-Dole Act (35 U.S.C. § 200 et seq.), domestic small businesses, educational institutions, and nonprofits may elect to retain title to their subject inventions;
- All other parties: The federal Non-Nuclear Energy Act of 1974, 42. U.S.C. 5908, provides that the government obtains title to new inventions unless a waiver is granted (see below);
- Class Patent Waiver:

  DOE has issued a class waiver that applies to this FOA. Under this class waiver, domestic large businesses may elect title to their subject inventions similar to the right provided to the domestic small businesses, educational institutions, and nonprofits by law. In order to avail itself of the class waiver, a domestic large business must agree that any products embodying or produced through the use of a subject invention first created or reduced to practice under this program will be substantially manufactured in the United States

- Advance and Identified Waivers: For an applicant not covered by a Class Patent Waiver or the Bayh-Dole Act, the applicant may request a patent waiver that will cover subject inventions that may be invented under the award, in advance of or within 30 days after the effective date of the award. Even if an advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver for identified inventions, i.e., individual subject inventions that are disclosed to EERE within the timeframes set forth in the award's intellectual property terms and conditions. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784.

- DEC : On June 07, 2021, DOE approved a DETERMINATION OF EXCEPTIONAL CIRCUMSTANCES (DEC) UNDER THE BAYH-DOLE ACT TO FURTHER PROMOTE DOMESTIC MANUFACTURE OF DOE SCIENCE AND ENERGY TECHNOLOGIES. In accordance with this DEC, all awards, including sub-awards, under this FOA shall include the U.S. Competitiveness Provision in accordance with Section IV.E.xv. U.S. Manufacturing Committments of this FOA. A copy of the DEC can be found at https://www.energy.gov/gc/determination-exceptional-circumstances-decs. Pursuant to 37 CFR § 401.4, any nonprofit organization or small business firm as defined by 35

U.S.C. 201 affected by any DEC has the right to appeal it by providing written notice to DOE within 30 working days from the time it receives a copy of the determination.

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 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 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 volunteer personnel hours, donated existing equipment, donated existing supplies. The cash value and calculations thereof for all In-Kind cost share items must be justified and explained in the Cost Share section of the project Budget Justification. All cost share items must be necessary to the performance of the project. If questions exist, consult your DOE contact before filling out the In-Kind cost share section of the Budget Justification.

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

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

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

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

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

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

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

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

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

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

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

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

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

(B) Valuing and documenting contributions

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

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

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

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

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

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

(4) Valuing property donated by third parties.

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

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

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

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

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

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

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

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

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

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

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

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

Each task must be calculated individually as follows:

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

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

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

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

The calculation may then be completed as follows:

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

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

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

1. Waiver for Foreign Entity Participation as the Prime Recipient

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

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

- Entity name;
- The rationale for proposing a foreign entity to serve as the prime recipient;
- Country of incorporation 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 E – GLOSSARY

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

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

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

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

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

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

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

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

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

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

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

APPENDIX F – DEFINITION OF TECHNOLOGY READINESS LEVELS

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

APPENDIX G – LIST OF ACRONYMS

COI	Conflict of Interest
DEC	Determination of Exceptional Circumstances
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