U.S. Department of Energy

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Program

Topics

FY 2020

Phase I

Release 2

Version 4, December 13, 2019

- Office of Cybersecurity, Energy Security, and Emergency Response
- Office of Defense Nuclear Nonproliferation
- Office of Electricity
- Office of Energy Efficiency and Renewable Energy
- Office of Environmental Management
- Office of Fossil Energy
- Office of Fusion Energy Sciences
- Office of High Energy Physics
- Office of Nuclear Energy

Schedule

Event	Dates
Topics Released:	Tuesday, November 12, 2019
Funding Opportunity Announcement Issued:	Monday, December 16, 2019
Letter of Intent Due Date:	Monday, January 06, 2020
Application Due Date:	Monday, February 24, 2020
Award Notification Date:	Monday, May 18, 2020*
Start of Grant Budget Period:	Monday, June 29, 2020

*** Date Subject to Change**

Table of Changes		
Version	**Date**	**Change**
Ver. 1	Nov. 12, 2019	Original
Ver. 2	Nov. 14, 2019	• Topic 6, subtopic a: Reference 1: Link Replacement • Topic 13, subtopic a: Changed "Hydraulic Design Center" to "Hydroelectric Design Center"
Ver. 3	Nov. 20, 2019	• Topic 6, subtopic a: Changed Subtopic Description • Topic 6, subtopic a: Reference 1: Corrected • Topic 6, subtopic c: Changed Point of Contact • Topic 6, subtopic d: Changed Subtopic Description • Topic 17, subtopic a: Changed Subtopic Description • Topic 17, subtopic b: Changed Subtopic Description • Topic 33: Added Subtopic e, Other • Topic 37, subtopic j: Subtopic Title Change • Topic 37, subtopic k: Changed Point of Contact
Ver. 4	Dec. 13, 2019	• Topic 1: Changed Topic Description • Topic 6, subtopic c: Formatting Change

[Return to Table of Contents](#)

INTRODUCTION TO DOE SBIR/STTR TOPICS

This SBIR/STTR topics document is issued in advance of the FY 2019 DOE SBIR/STTR Phase I Release 2 Funding Opportunity Announcement scheduled to be issued on November 26, 2018. The purpose of the early release of the topics is to allow applicants an opportunity to identify technology areas of interest and to begin formulating innovative responses and partnerships. Applicants new to the DOE SBIR/STTR programs are encouraged to attend upcoming topic and Funding Opportunity Announcement webinars. Dates for these webinars are listed on our website: https://science.osti.gov/sbir/Funding-Opportunities.

Topics may be modified in the future. Applicants are encouraged to check for future updates to this document, particularly when the Funding Opportunity Announcement is issued. Any changes to topics will be listed at the beginning of this document.

General introductory information about the DOE SBIR/STTR programs can be found online here: http://www.doesbirlearning.com/. Please check out the tutorials--a series of short videos designed to get you up to speed quickly.

COMMERCIALIZATION

Federal statutes governing the SBIR/STTR programs require federal agencies to evaluate the commercial potential of innovations proposed by small business applicants. To address this requirement, the DOE SBIR/STTR programs require applicants to submit commercialization plans as part of their Phase I and II applications. DOE understands that commercialization plans will evolve, sometimes significantly, during the course of the research and development, but investing time in commercialization planning demonstrates a commitment to meeting objectives of the SBIR/STTR programs. During Phase I and II awards, DOE provides small businesses with commercialization assistance through a DOE-funded contractor.

The responsibility for commercialization lies with the small business. DOE's SBIR/STTR topics are drafted by DOE program managers seeking to advance the DOE mission. Therefore, while topics may define important scientific and technical challenges, we look to our small business applicants to define how they will bring commercially viable products or services to market. In cases where applicants are able identify a viable technical solution, but unable to identify a successful commercialization strategy, we recommend that they do not submit an SBIR/STTR application.

TECHNOLOGY TRANSFER OPPORTUNITIES

Selected topic and subtopics contained in this document are designated as **Technology Transfer Opportunities (TTOs)**. The questions and answers below will assist you in understanding how TTO topics and subtopics differ from our regular topics.

What is a TTO?

A TTO is an opportunity to leverage technology that has been developed at a university or DOE National Laboratory. Each TTO will be described in a particular subtopic and additional information may be obtained by using the link in the subtopic to the university or National Laboratory Contractor that has developed the technology. Typically the technology was developed with DOE funding of either basic or applied research and is available for transfer to the private sector. The level of technology maturity will vary and applicants are encouraged to contact the appropriate university or Laboratory Contractor prior to submitting an application.

How would I draft an appropriate project description for a TTO?
For Phase I, you would write a project plan that describes the research or development that you would perform to establish the feasibility of the TTO for a commercial application. The major difference from a regular subtopic is that you will be able to leverage the prior R&D carried out by the university or National Laboratory Contractor and your project plan should reflect this.

How do I draft a subaward?
The technology transfer office of the collaborating university or DOE Laboratory will typically be able to assist with a suitable template.

Am I required to show I have a subaward with the university or National Laboratory Contractor that developed the TTO in my grant application?
No. Your project plan should reflect the most fruitful path forward for developing the technology. In some cases, leveraging expertise or facilities of a university or National Laboratory Contractor via a subaward may help to accelerate the research or development effort. In those cases, the small business may wish to negotiate a subaward with the university or National Laboratory.

Is the university or National Laboratory Contractor required to become a subawardee if requested by the applicant?
No. Collaborations with universities or National Laboratory Contractors must be negotiated between the applicant small business and the research organization. The ability of a university or National Laboratory Contractor to act as a subcontractor may be affected by existing or anticipated commitments of the research staff and its facilities.

Are there patents associated with the TTO?
The TTO will be associated with one or in some cases multiple patent applications or issued patents.

Will the rights to the TTO be exclusive or non-exclusive?
Each TTO will describe whether an exclusive or non-exclusive license to the technology is available for negotiation. Licenses are typically limited to a specific field of use.

If selected for award, what rights will I receive to the technology?
Those selected for award under a TTO subtopic, will be granted rights to perform research and development of the technology during their Phase I or Phase II grants. Please note that these are NOT commercial rights which allow you to license, manufacture, or sell, but only rights to perform research and development. In addition, an awardee will be provided a no-cost, six month option to license the technology at the start of the Phase I award. It will be the responsibility of the small business to demonstrate adequate progress towards commercialization and negotiate an extension to the option or convert the option to a license. A copy of an option agreement template will be available at the university or National Laboratory Contractor which owns the TTO.

How many awards will be made to a TTO subtopic?
We anticipate making a maximum of one award per TTO subtopic. If we receive applications to a TTO that address different fields of use, it is possible that more than one award will be made per TTO.

Return to Table of Contents

How will applying for an SBIR or STTR grant associated with a TTO benefit me?
By leveraging prior research and patents from a university or National Laboratory Contractor you will have a significant "head start" on bringing a new technology to market. To make greatest use of this advantage it will help for you to have prior knowledge of the application or market for the TTO.

Is the review and selection process for TTO topics different from other topics?
No. Your application will undergo the same review and selection process as other applications.

ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

The Department of Energy is prioritizing the use of artificial intelligence and machine learning to advance its mission. Artificial intelligence and machine learning are important enablers for the specific topics and subtopics listed below.

Office Energy Efficiency and Renewable Energy:

12. VEHICLES
    c. Research on Energy Efficiency in Emerging Mobility Systems
13. WATER
    b. Innovative Sensing and Data Platforms for Water and Hydropower
14. WIND
    c. Other

Office of Fossil Energy:

19. ADVANCED TURBINES TECHNOLOGIES
    b. Sensors for Turbine Applications

Office of High Energy Physics:

30. ADVANCED CONCEPTS AND TECHNOLOGY FOR PARTICLE ACCELERATORS
    g. Accelerator Machine Learning and Controls

Office of Nuclear Energy:

37. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY
    a. Advanced Sensors and Instrumentation (Crosscutting Research)

Return to Table of Contents

PROGRAM AREA OVERVIEW: OFFICE OF CYBERSECURITY, ENERGY SECURITY, AND EMERGENCY RESPONSE

The Office of Cybersecurity, Energy Security, and Emergency Response (CESER) leads the Department of Energy's emergency preparedness and coordinated response to disruptions to the energy sector, including physical and cyber-attacks, natural disasters, and man-made events. Cybersecurity for Energy Delivery Systems (CEDS) is a program within the CESER office that works to develop innovative technologies to aid power systems in adapting to and surviving from potential cyberattacks.

The CEDS program leverages its partnerships with stakeholders within electricity generation, transmission, and distribution along with entities that represent the secure delivery of natural gas and petroleum to guide technology development that enhances energy systems cybersecurity without impeding normal operations. Research funding is provided to a diverse range of researchers representing asset owners/operators, supply chain vendors, national laboratories, and academia. All CEDS funded research is intended for demonstration with an entity that represents the potential user of the technology to aid technology transition into wide area adoption.

For additional information regarding CESER's activities and priorities, click here. Information regarding current CEDS' funding can be found here.

Further information regarding the challenges and needs associated with the cybersecurity of the Nation's energy infrastructure can be found in the 2018 releases of the Department's Multiyear Plan for Energy Sector Cybersecurity.

1. ENERGY SYSTEMS CYBERSECURITY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

Research in cybersecurity for energy delivery systems is focused on enhancement of operational technology (OT) that aids power systems to adapt and survive from a cyberattack and continue safe operations. This OT is the computers and networks that manage, monitor, protect, and control operations of energy delivery systems. This research topic requests proposals to develop proof of concept for unique and innovative features to existing tools and technologies that address a need for the cyber security of power systems operations. Selected proposals must include a scope of work that will lead up to, but will not include, the development of a demonstration prototype.

All applications to subtopics under this topic must:

- Propose a tightly structured project which includes technical and business milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- For any solution intended for onsite installation; fully justify the compatibility with the electro-magnetic and environmental conditions of the intended site;
- Clearly describe the commercialization potential of the federally-funded effort and provide a detailed path to scale up in potential transition to industry practice.
- Fully justify the future potential for demonstration with an asset owner/operator who is an intended user.

All applications to subtopics under this topic should:

- Clearly define the merit of the proposed innovation compared to competing approaches and the anticipated outcome.
- Be consistent with and have performance metrics (whenever possible) linked to published, authoritative analyses in your technology space.
- Include quantitative projections for price and/or performance improvement that are tied to representative values included in authoritative publications or in comparison to existing products.
- Fully justify all performance claims with thoughtful theoretical predictions and/or experimental data.

Grant applications are sought in the following subtopics:

a. Cybersecurity during Contingency Operations

This subtopic area is for the development of tools and technologies that ensure secure access to energy delivery systems OT during contingency operations. Maintaining control and system/network visibility is paramount during restoration efforts, particularly those involving "black start" techniques. This capability must be timely and secure to prevent any interruption in operations where possible, and to facilitate restoration in the event of outage. This tool must also not hinder the work that must be done to transition from contingency to normal operations of the energy delivery system and should be flexible and quickly deployable. To the extent possible its communications footprint should be light enough to function in situations where normal utility communications paths are disrupted.

Questions – Contact: Walter Yamben, Walter.Yamben@netl.doe.gov

b. Power Systems Settings Security

This subtopic is for the development of tools, technologies, and methodologies that prevent malicious alterations of power systems settings. This technology can include but is not limited to means of detecting a cyber intrusion; detecting alterations to critical settings; and controlling access to energy delivery systems settings.

Questions – Contact: Walter Yamben, Walter.Yamben@netl.doe.gov

References:

1. American Petroleum Institute, 2014, State of Operational Technology Cybersecurity in the Oil and Natural Gas Industry, p. 82. www.api.org/~/media/Files/Policy/Cybersecurity/Operational-Technologies-Guidance-Doc-Apr14.pdf

2. Office of Electricity Delivery and Energy Reliability, 2018, Multiyear Plan for Energy Sector Cybersecurity, United States Department of Energy, p. 52. www.energy.gov/sites/prod/files/2018/05/f51/DOE%20Multiyear%20Plan%20for%20Energy%20Sector%20Cybersecurity%20_0.pdf

3. Energy Sector Control Systems Working Group, 2011, Roadmap to Achieve Energy Systems Cybersecurity, United States Department of Energy, p. 75. www.energy.gov/sites/prod/files/Energy%20Delivery%20Systems%20Cybersecurity%20Roadmap_finalweb.pdf

Return to Table of Contents

4. National Institute of Standards and Technology, 2014, Smart Grid Cybersecurity Stategy, Architechture, and High-Level Requirements, Guidelines for Smart Grid Cyber Security, Vol. 1-2, NISTIR 7628, p. 668. https://nvlpubs.nist.gov/nistpubs/ir/2014/NIST.IR.7628r1.pdf

5. IEEE Standards Association, 2015, C37.240-2014 - IEEE Standard Cybersecurity Requirements for Substation Automation, Protection, and Control Systems. https://ieeexplore.ieee.org/document/7024885

6. National Energy Reliability Corporation, 2017, Reference Document Risks and Mitigations for Losing EMS Functions. https://www.nerc.com/comm/OC/ReferenceDocumentsDL/Risks_and_Mitigations_for_Losing_EMS_Functions_Reference_Document_20171212.pdf

7. North American Transmission Forum, 2017, Bulk Electric Systems Operations Absent Energy Management System and Supervisory Control and Data Acquisition Capabilities—a Spare Tire Approach. http://www.natf.net/docs/natf/documents/resources/resiliency/natf-bes-operations-absent-ems-and-scada-capabilities---a-spare-tire-approach.pdf

Return to Table of Contents

PROGRAM AREA OVERVIEW: OFFICE OF DEFENSE NUCLEAR NONPROLIFERATION RESEARCH AND DEVELOPMENT

The Defense Nuclear Nonproliferation (DNN) mission is to provide policy and technical leadership to limit or prevent the spread of materials, technology, and expertise relating to weapons of mass destruction; advance the technologies to detect the proliferation of weapons of mass destruction worldwide; and eliminate or secure inventories of surplus materials and infrastructure usable for nuclear weapons. It is the organization within the Department of Energy's National Nuclear Security Administration (NNSA) responsible for preventing the spread of materials, technology, and expertise relating to weapons of mass destruction (WMD).

Within DNN, the Defense Nuclear Nonproliferation Research and Development (DNN R&D) program directly contributes to nuclear security by developing capabilities to detect and characterize global nuclear security threats. The DNN R&D program also supports cross-cutting functions and foundational capabilities across nonproliferation, counterterrorism, and emergency response mission areas. Specifically, the DNN R&D program makes these strategic contributions through the innovation of U.S. technical capabilities to detect, identify, locate, and characterize: 1) foreign nuclear material production and weapons development activities; 2) movement and illicit diversion of special nuclear materials; and 3) global nuclear detonations.

To meet national and Departmental nuclear security requirements, DNN R&D leverages the unique facilities and scientific skills of DOE, academia, and industry to perform research and demonstrate advances in capabilities, develop prototypes, and produce sensors for integration into operational systems.

DNN R&D has two sub-Offices: Proliferation Detection and Nuclear Detonation Detection.

The Office of Proliferation Detection (PD) develops advanced technical capabilities in support of the following three broad U.S. national nuclear security and nonproliferation objectives: (1) detect, characterize, and monitor foreign production and movement of special nuclear materials; (2) detect, characterize, and monitor foreign development of nuclear weapons and to support the nuclear counterterrorism and incident response mission; and (3) provide enabling capabilities for multi-use applications across the NNSA and interagency community.

The Office of Nuclear Detonation Detection (NDD) performs the following three national nuclear security roles: (1) produce, deliver, and integrate the nation's space-based operational sensors that globally detect and report surface, atmospheric, or space nuclear detonations; (2) advance seismic and radionuclide detection and monitoring capabilities that enable operation of the nation's ground-based nuclear detonation detection networks; and (3) advance analytic nuclear forensics capabilities related to nuclear detonations.

For additional information regarding the Office of Defense Nuclear Nonproliferation Research and Development priorities, click here.

2. RADIATION DETECTION

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

The Office of Proliferation Detection (PD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to develop new technologies for radiation detection. Meeting this objective requires the improvement of current technology and the development of new materials and tools for radiation detection applications. Grant applications are sought in the following subtopics:

a. Radiation Detection Material Advancement

Ceramic material research – Research on scintillating ceramics is needed. Research to optimize optically transparent ceramics that can rival bulk crystal growth methods may enable lower cost, larger volume, and better energy resolution than sodium iodide based systems. Ceramic scintillators that are dense (>5 g/cm^3), have high effective Z (>60), are bright (>40,000 photons/MeV), and are not sensitive to moisture and can be handled without protection are desired. Ultra-fast ceramic materials are also of interest. Possible methods include consolidation of powders, time-temperature-pressure cycles, isostatic pressing, or other approaches.

High-Z, Wide Bandgap Semiconductors – Very high-resolution gamma detection remains an enduring need. Significant progress has occurred to improve both performance and cost of existing commercial materials, but continued research is needed to achieve desired material performance in both identified and undiscovered materials. Successful proposals will identify pathways for mitigating known risks and challenges, such as: 1) better understanding of defect tolerance toward improving detector resolution; 2) demonstration of stable, long-term detection performance; 3) demonstration of crystals scalable to much larger volumes than currently demonstrated in candidate materials; 4) demonstrating very high yield of detector quality material over existing materials. Development of fundamental modeling capabilities to address these known challenges is encouraged as part of an experimental effort.

Questions – Contact: Donald Hornback, Donald.Hornback@nnsa.doe.gov

b. Portable Neutron, X-ray, and Multi-Modal Radiography

Sources, detection materials, and instrumentation to enable improved high-resolution x-ray and neutron radiography/imaging is sought. Improved capability requires development of both portable sources and portable imaging systems. While portable commercial systems are primarily limited to x-ray imaging, neutron imaging capability with similar spatial resolution to x-rays is desired. An ideal system would provide combined x-ray/neutron imaging capability.

Imaging systems: Existing approaches include pixilation of scintillator materials and the use of conversion screens that use film or storage phosphors. Technical solutions that enable mobile use and fast, simple image acquisition are preferred. Passive imaging including Compton camera and coded imaging are not desired. Ideal candidates will demonstrate low size, weight, and power capabilities or a pathway towards portable detectors similar, in principle, to flat-panel x-ray detectors or film used in digital radiography.

Sources: Ultra-portable x-ray and neutron systems capable of field-use are desired. X-ray end-point energies of no more than 2.5 MeV and deuterium-deuterium or deuterium-tritium neutron generators are appropriate.

Questions – Contact: Donald Hornback, Donald.Hornback@nnsa.doe.gov

c. Other

In addition to the specific subtopics listed above, grant applications in other areas relevant to this topic are invited.

Questions – Contact: Donald Hornback, Donald.Hornback@nnsa.doe.gov

Return to Table of Contents

3. DESIGN AND MANUFACTURING ADVANCES FOR SPACE-BASED SENSORS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

The Office of Nuclear Detonation Detection (NDD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) is seeking innovative design ideas and capabilities for sensors used in future space-based nuclear detonation detection systems. These systems continuously monitor the globe to detect, report, locate, identify, and characterize nuclear explosions. Grant applications are sought in the following subtopics:

a. Next-Generation Miniaturized Ionizing Radiation Sensors

NDD seeks novel technology proof-of-concepts for space-based sensors to detect and record signals in ionizing radiation regimes [1, 2]. Use of high-performing sensor technology can help advance mission goals to increase the accuracy, longevity, and efficiency of the sensor network.

Grant applications are sought to research sensors, techniques, or capabilities that can detect signal intensities and/or spectral features as a function of time, in ways that are functional and resilient in space environments as well as being potentially small and/or lightweight [1, 2, 3].

For example, research is sought to lead to developments in fabrication technology that can miniaturize one or more sensors (e.g., “sensor-on-a-chip” concepts [4]) in ways that preserve their ability to function in space environments. Constraining space application requirements include temperature cycles, shock, vibration, radiation, vacuum, contamination, electromagnetic interference, and compatibility [5]. One interest is to estimate size, weight, power, and cost of each such miniaturized sensor option, and trade-offs among these parameters. Proposers should show an understanding of the signal characteristics that can be detected by a miniaturized sensor, and controlling technical specifications that define the performance envelope. A successful development could have other applications where sensor size and/or weight are constrained.

Questions – Contact: Lt Col Robert Heyward, Robert.heyward@nnsa.doe.gov

b. Manufacturing Developments for Silicon Photodiodes

Satellite-based observations of nuclear detonations improved since first introduced in the mid-1960s, largely enabled by improvements to silicon photodiodes that reduce noise and leakage current over a large area. Silicon photodiodes are currently available from foreign manufacturers for terrestrial applications, but few are available from domestic suppliers to meet national security space applications. Constraining space application requirements include temperature cycles, shock, vibration, radiation, vacuum, contamination, electromagnetic interference and compatibility [1].

Grant applications are sought to research ways to create manufacturable designs that produce photodiodes with very low noise ($1.3\text{x}10^{-13}$ $W/Hz^{1/2}$) for a 200 mm^2 active area with leakage current below 30 nA at full depletion voltage of 120V [2]. Research to attain these attributes could include techniques to grow and produce high-purity semiconductor materials, in order to achieve high breakdown voltage and low dark current noise. Research could also explore attaining similar functionality using tuned optical antennas [3, 4], which may have potential for supplanting photodiodes in space applications. A successful proposal will include proof-of-concept and may suggest alternative applications.

Questions – Contact: Lt Col Robert Heyward, Robert.heyward@nnsa.doe.gov

c. Space Qualified Printed Circuit Boards Produced Via Additive Manufacturing

Production of printed circuit boards (PCBs) with additive manufacturing (AM) technologies is a developing technology with potential for a wide range of applications. Despite these advances, the applicability of the technology to the rigors of space launch and flight environments has not yet been proven. NDD could benefit from using AM technologies for PCBs in the following ways: expedited development via rapid prototyping of new quick-turn design modifications, increased integration of constituent electronic components, and the ability to provide new capabilities not previously available in PCB manufacturing, such as the ability to print passive components (termination resistors and by-pass capacitors) directly into the PCB, thereby reducing board area and component assembly complexity. Additionally, AM may provide improved precision for minimizing conductor widths, conductor separation, and layer separation.

Grant applications are sought to research, evaluate, and demonstrate via proof-of-concept the feasibility of additively manufacturing PCBs that would meet the requirements of space launch and flight. Constraining space application requirements include temperature cycles, shock, vibration, radiation, vacuum, contamination, electromagnetic interference and compatibility [1]. The thermal properties of AM PCBs need to provide conduction cooling of the electronic components similar to, or better than, conventional PCBs. The desired performance is IPC-6012 Class 3 [3]. A potential research goal is to demonstrate an AM-based technology via the production of a prototype(s) multi-layer PCB that meets the rigorous space flight qualification specifications of [1, 2].

Questions – Contact: Lt Col Robert Heyward, Robert.heyward@nnsa.doe.gov

d. Other:

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above [1, 2, 3].

Questions – Contact: Lt Col Robert Heyward, Robert.heyward@nnsa.doe.gov

References: Subtopic a:

1. Los Alamos National Laboratory, 2018, Los Alamos sensors watch for potential nuclear explosions, Science Briefs, https://www.lanl.gov/discover/news-stories-archive/2018/January/0131-vela-to-cubesats.php

2. Crow, R., Crow, K., Preston, R., et al, 2017, Advanced Maui Optical and Space Surveillance Technologies Conference, Hyperspectral Measurements of Space Objects with a Small Format Sensor System, Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS), Wailea, https://amostech.com/TechnicalPapers/2017/Poster/Beecher.pdf

3. Higbie, P.R., Blocker, N.K., Detecting Nuclear Detonations with GPS, GPS World: News and Applications of the Global Positioning System, February 1994, https://www.osti.gov/servlets/purl/10185731

4. Poulton, C.V., Watts, M.R., 2016, MIT and DARPA Pack Lidar Sensor Onto Single Chip, IEEE Spectrum, https://spectrum.ieee.org/tech-talk/semiconductors/optoelectronics/mit-lidar-on-a-chip

5. NASA Goddard Space Flight Center, 2019, General Environmental Verification Standard (GEVS), GSFC-STD-7000A, Greenbelt, MD, https://standards.nasa.gov/standard/gsfc/gsfc-std-7000

References: Subtopic b:

1. NASA Goddard Space Flight Center, 2019, General Environmental Verification Standard (GEVS), GSFC-STD-7000A, Greenbelt, MD, https://standards.nasa.gov/standard/gsfc/gsfc-std-7000

2. Bharadwaj, P., Deutsch, B., Novotny, L., 2009, Optical Antennas, Advances in Optics and Photonics, vol. 1, no. 3, pp. 438--483, https://www.osapublishing.org/aop/abstract.cfm?URI=aop-1-3-438

3. Hecht, J., 2013, Optical antennas concentrate light and direct beams, Laser Focus World, 16 09, https://www.researchgate.net/publication/295658568_Optical_antennas_concentrate_light_and_direct_beams

References: Subtopic c:

1. NASA Goddard Space Flight Center, 2019, General Environmental Verification Standard (GEVS), GSFC-STD-7000A, Greenbelt, MD, https://standards.nasa.gov/standard/gsfc/gsfc-std-7000

2. Air Force Space Command Space and Missile Systems Center Standard, Test Requirements for Launch, Upper-Stage, and Space Vehicles, SMC-S-016, https://www.afspc.af.mil/About-Us/Fact-Sheets/Display/Article/1012587/space-and-missile-systems-center/

3. IPC-6012D, Qualification and Performance Specification for Rigid Printed Boards, http://www.ipc.org/TOC/IPC-6012D.pdf

References: Subtopic d:

1. NASA, 2018, Aeronautics and Space Report of the President, Fiscal Year 2017 Activities https://history.nasa.gov/presrep2017.pdf

2. DOE/NNSA (2019). Prevent, Counter, and Respond – A Strategic Plan to Reduce Global Nuclear Threats FY 2020-FY 2024 Report to Congress (July 2019), https://www.energy.gov/nnsa/downloads/prevent-counter-and-respond-strategic-plan-reduce-global-nuclear-threats-npcr

3. Higbie, P.R., Blocker, N.K., Detecting Nuclear Detonations with GPS, GPS World: News and Applications of the Global Positioning System, February 1994, https://www.osti.gov/servlets/purl/10185731

PROGRAM AREA OVERVIEW: OFFICE OF ELECTRICITY

The Office of Electricity (OE) provides national leadership to ensure that the Nation's energy delivery system is secure, resilient, and reliable. OE works to develop new technologies to enhance the infrastructure that brings electricity into our homes, offices, and factories and to improve the federal and state electricity policies and programs that shape electricity system planning and market operations. OE also works on solutions that bolster the resiliency of the electric grid and assists with restoration when major energy supply interruptions occur.

As the lead for the Department of Energy's efforts on grid modernization, OE works closely with diverse stakeholders to ensure that clean energy technologies can be integrated in a safe, reliable, and cost-effective manner. OE leverages effective partnerships, solid research, and best practices to address diverse interests in achieving economic, societal, and environmental objectives.

For additional information regarding OE's activities and priorities, click here.

Further information regarding the challenges and needs associated with the Nation's energy infrastructure can be found in the 2015 releases of the Department's Quadrennial Energy Review and Quadrennial Technology Review.

4. ADVANCED GRID TECHNOLOGIES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

The electric power grid is facing fundamental changes in both supply-side and demand-side technologies. On the supply-side, there is a shift from large synchronous generators (e.g., coal, nuclear) to smaller units (e.g., gas-fired turbines) and variable energy resources (e.g., renewables). On the demand-side, there is a growing number of distributed energy resources, as well as the increasing use of electronic converters in buildings, industrial equipment, and consumer devices. The monitoring, control, and protection systems used for grid operations are also transitioning from analog systems to systems with increasing data streams and more digital control and communications; from systems with a handful of control points at central stations to ones with potentially millions of control points. Furthermore, increasing risks posed by extreme weather events, cyber threats, and physical attacks presents new challenges with system security, reliability, and resilience. In essence, the grid we have today was not designed for today's requirements and will demand next-generation grid technologies.

All applications to subtopics under this topic should:

- Be consistent with and have performance metrics (whenever possible) linked to published, authoritative analyses in your technology space.
- Clearly define the merit of the proposed innovation compared to competing approaches and the anticipated outcome.
- Emphasize the commercialization potential of the overall effort and provide a path to scale up in potential Phase II follow-on work.
- Include quantitative projections for price and/or performance improvement that are tied to representative values included in authoritative publications or in comparison to existing products.
- Fully justify all performance claims with thoughtful theoretical predictions and/or experimental data.

Return to Table of Contents

Grant applications are sought in the following subtopics:

a. Power System Operator Human Factors Innovation

The American Recovery and Reinvestment Act (ARRA) investments rapidly increased the amount of data available for system operators through the deployment of new sensors, such as the phasor measurement unit (PMU). Visibility into the power system is now at an unprecedented level and forecasted to increase. While the energy industry is producing larger volumes of data at faster rates, with greater variety, new tools and best practices to visualize and process data are needed. Understanding what system operators require to make informed decisions and analysis, human factors innovation in visualization and decision making can enable more effective alarming, cueing, and corrective action.

At the same time that there is more data being generated within electricity, there are also connected systems, like communications and natural gas, which are becoming more and more interdependent with electricity. Current visualization tools are specific to their individual sectors, and this makes developing visualization tools that combine sector data challenging, particularly because of the added complexity. Additionally, system operators are facing these new challenges as the workforce is aging – stressing existing operator training norms. New methods or simulators for training system operators are needed to help train the changing workforce.

This subtopic aims to advance and develop human factors understanding and visualization methods, tools, and techniques for utility system operators and for training.

Applications to this subtopic should consider:

- State of the art of human factors research
- State of the art visualization methods, including tools not traditionally used in the power sector
- User training and ease of user experience
- Multi-sector system overlays and visualization
- Alarming and cueing for system operators
- New data streams, such as PMUs or other advance sensing technologies
- Data storage and sharing guidance
- Alignment of metadata across platforms and sectors
- Security and privacy methods and practices for insuring data is protected

Collaboration with power system operators and utility engineers is strongly encouraged.

Questions – Contact: Sandra Jenkins, sandra.jenkins@hq.doe.gov

b. Advanced Power Transmission Tools and Technologies

While the electric power system is undergoing rapid changes in supply-side and demand-side technologies, the transmission backbone for bulk power accommodated and facilitated these developments while remaining fundamentally unchanged. As this infrastructure is aging and becoming more stressed with new types of generation that require more rapid flow control for balancing and congestion management, weather and wildfire resilience is also becoming a growing concern. New types of control software have improved the ability to predict and mitigate some of these issues, however utilities and system operators remain limited by the physical capabilities of the equipment on their system.

Attractive areas for development of renewable resources are sometimes far from load centers and the cost of building long distance transmission can hinder investment and access to markets. Additionally, permitting new lines can be a challenge when crossing multiple state and federal jurisdictions, especially when there are negative impacts on nearby communities. Both disruptive and incremental innovations to facilitate or enhance power transmission and delivery over long distances, with or without wires, are needed to provide additional system flexibly, security, and resilience.

This subtopic aims to develop technologies, methodologies, processes, materials, or tools that will advance the state of the art of bulk power transmission.

Desired characteristics and capabilities include:

- Lower physical footprint
- Lower costs across long distances
- Environmental and safety considerations
- Improved resilience to weather and wildfires
- Flexible operation and dynamic control
- Ease of maintenance
- Efficiency of power delivery or transfer

Questions – Contact: Kerry Cheung, kerry.cheung@hq.doe.gov

References: Subtopic a:

1. Stevens-Adams, S., Cole, K., Haass, M., et al, 2015, Situation Awareness and Automation in the Electric Grid Control Room, Procedia Manufacturing, Volume 3, Pages 5277-5284, ISSN 2351-9789, https://doi.org/10.1016/j.promfg.2015.07.609, http://www.sciencedirect.com/science/article/pii/S2351978915006101

2. Fink, R., Hill, D., O'Hara, J., 2004, Human Factors Guidance for Control Room and Digital Human-System Interface Design and Modification, U.S. Department of Energy, doi: 10.2172/835085, https://www.osti.gov/servlets/purl/835085

3. Federal Aviation Administration, Human Factors Division, https://www.hf.faa.gov/

4. ABB, How to Enhance Control Room Operator Capacities: Human Factors and Ergonomics, https://new.abb.com/control-rooms/features/how-to-enhance-control-room-operator-capacities

References: Subtopic b:

1. MIT Energy initiative, 2011, Future of the Electric Grid, http://energy.mit.edu/research/future-electric-grid/

2. U.S. Department of Energy, 2019, Dynamic Line Rating, Report to Congress June 2019, https://www.energy.gov/sites/prod/files/2019/08/f66/Congressional_DLR_Report_June2019_final_508_0.pdf

3. U.S. Energy Information Administration, 2018, Assessing HVDC Transmission for Impacts of Non-Dispatchable Generation, Independent Statistics & Analysis, https://www.eia.gov/analysis/studies/electricity/hvdctransmission/pdf/transmission.pdf

4. U.S. Department of Energy, 2015, Quadrennial Energy Review: First Installment, Office of Policy, https://www.energy.gov/policy/initiatives/quadrennial-energy-review-qer/quadrennial-energy-review-first-installment

5. U.S. Department of Energy, 2002, National Transmission Grid Study: Issue Papers, https://www.ferc.gov/industries/electric/gen-info/transmission-grid.pdf

6. United States Federal Power Commission, 1974, National Power Survey: Research and Development for the Electric Utility Industry: the Report and Recommendations of the Technical Advisory Committee on Research and Development, Technical Advisory Committee on Research and Development, Chapter 5.5.8, Pg. 5.11. https://books.google.com/books?id=QidHAQAAIAAJ&lpg=SA5-PA12&ots=yxbUrz7Aom&dq=%22a%20study%20for%20the%20national%20science%20foundation%22%20energy%20distribution%20research&pg=SA5-PA1#v=onepage&q&f=false

7. Agbinya, J.I., Ali Mohamed, N.F., 2014, Design and Study of Multi-dimensional Wireless Power Transfer Transmission Systems and Architectures, International Journal of Electrical Power & Energy Systems, Volume 63, Pages 1047-1056, ISSN 0142-0615, https://doi.org/10.1016/j.ijepes.2014.06.071.

8. Christiano, M., 2016, Introduction to Wireless Power Transfer, AllAboutCircuits, https://www.allaboutcircuits.com/technical-articles/introduction-to-wireless-power-transfer-wpt/

5. SAFETY TECHNOLOGIES FOR GRID SCALE BATTERY ENERGY STORAGE SYSTEMS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

The United States generated approximately 4 trillion kWh of electricity in 2018. As the nation's demand for electricity shows no sign of decline, energy diversification through the utilization of fossil, nuclear, and renewable sources become of paramount importance. Battery Energy Storage Systems (BESS) play a critical role in enabling the dispatchability of renewable energy technologies with variable outputs. As BESS become more prevalent as a Grid Scale Energy Storage Systems (ESS) option, special consideration must be taken in relation to their safety and reliability, especially due to the possibility of thermal runaway. The development and utilization of technologies that enhance the safety and reliability of BESS in operation, and emergency response capabilities after an incident remains a challenge.

All applications to subtopics under this topic should:

- Be consistent with and have performance metrics (whenever possible) linked to published, authoritative analyses in your technology space.
- Clearly define the merit of the proposed innovation compared to competing approaches and the anticipated outcome.
- Emphasize the commercialization potential of the overall effort and provide a path to scale up in potential Phase II follow-on work.
- Include quantitative projections for price and/or performance improvement that are tied to representative values included in authoritative publications or in comparison to existing products.
- Fully justify all performance claims with thoughtful theoretical predictions and/or experimental data.

Grant applications are sought in the following subtopics:

a. Thermal Runaway Prevention Technologies for Lithium-Ion Batteries

Lithium-ion batteries have gained significant interest as a Grid Scale ESS option given their high energy density and voltage, and recent cost reductions. One of the main concerns with the more prevalent utilization of grid-scale lithium-ion batteries is in regards to safety and the effects of thermal runaway.

Thermal runaway in lithium-ion batteries refers to an uncontrollable exothermic reaction triggered by elevated temperatures. As the temperature of the battery rises above 80°C, the exothermic reaction further increases and heats up the cell, creating a positive feedback cycle. Thermal runaway events can result in the battery cell rapidly releasing its stored energy, fires, and explosions. It can be initiated through a variety of abuse mechanisms such as thermal abuse, overcharge, over-discharge, and mechanical abuse. Current detection mechanisms for thermal runaway in lithium-ion cells is when the measured voltage drops and the temperature increase in the cell is greater than 4°C/s.

Despite recent safety monitoring advances in battery management systems (BMS), the prevention of thermal runaway remains a challenge to the safe and reliable application of grid-scale lithium-ion batteries. Some of the internal protective devices currently used are PTCs (Positive Temperature Coefficient) and CIDs (Current Interrupt Device). However, additional innovations are needed.

This subtopic aims to develop technologies, methodologies, processes, materials, or tools to prevent or mitigate thermal runaway in grid-scale lithium-ion batteries.

Desired characteristics and capabilities include:

- Cost-competitiveness
- Durability (i.e., able to withstand varying pressures and temperatures)
- Low-hazard and safe for rapid deployment
- Compliant with safety standards

Questions – Contact: Andre Pereira, andre.pereira@hq.doe.gov

b. Battery Energy Storage Systems Emergency Response Technologies

The safe application of BESS must be accomplished through high levels of system reliability, and the ability to react promptly and safely to an incident. However, fires associated with BESS thermal runaway are occurring with troubling frequency and the emergency response experience is still limited. For instance, in April 2019, the Arizona Public Service (APS) McMicken Battery Energy Storage facility caused a fire and explosion that seriously injured four firefighters responding to the incident; highlighting the challenges and risks that grid-scale BESS incidents might pose to first responders. Some of the challenges associated with incident response relate to the constant risk of re-ignition, and the flammable and toxic gases present in a battery fire such as: Carbon Dioxide (CO_2), Carbon Monoxide (CO), Ethylene (C_2H_4), Hydrogen (H_2), and Methane (CH_4).

The development and utilization of remotely operated emergency response technologies (e.g., Drones, UAVs, Robots, etc.) can play an important role in reducing first responders' exposure to potential hazards. Suitable remotely operated emergency response technologies will have thermal-imaging and multi-gas detection capabilities to improve situational awareness. Additionally, the reoccurrence of BESS fire-related incidents indicates that improvements in fire suppression systems might be needed. Some of the possible areas of improvement include suppressant selection (e.g., Water, Clean Agent, etc.), storage configuration, quantities, arrangements, and overall effectiveness.

This subtopic aims to develop technologies, methodologies, processes, materials, or tools that will enhance emergency response capabilities for BESS fires and incidents.

Desired characteristics and capabilities include:

- Durable and able to operate in hazardous environments
- Enhances situational awareness
- Supports visual navigation
- Cost-competitiveness
- Easy to use and safe for rapid deployment
- Long range (i.e., ability to be operated from a safe distance)
- Compliant with safety standards (e.g., NFPA 855)

Questions – Contact: Andre Pereira, andre.pereira@hq.doe.gov

References: Subtopic a:

1. Zablocky, A., 2019, Fact Sheet: Energy Storage, 2019, Environmental and Energy Study Institute, https://www.eesi.org/papers/view/energy-storage-2019

2. Bandhauer, T.M., Garimella, S., Fuller, T. F., 2011, A Critical Review of Thermal Issues in Lithium-Ion Batteries, Journal of the Electrochemical Society, 158 (3) R1-R25. http://jes.ecsdl.org/content/158/3/R1.full.pdf+html

3. Döring, H., Wörz, M., 2018, Initializing of Thermal Runaway for Lithium-Ion Cells, Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), https://ec.europa.eu/jrc/sites/jrcsh/files/initializing-of-thermal-runaway-for-lithium-ion-cells.pdf

4. Galushkin, N.E., Galushkin, D.N., Yazvinskaya N.N., 2018, Mechanism of Thermal Runaway in Lithium-Ion Cells, Journal of The Electrochemical Society, 165 (7) A1303-A1308. http://jes.ecsdl.org/content/165/7/A1303

5. Manzo, M.A., Brewer, J.C., Bugga, R.V., et al, 2010, NASA Aerospace Flight Battery Program, The National Aeronautics and Space Administration, p. 15, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100028067.pdf

References: Subtopic b:

1. Colthrope, A., 2019, Korea's ESS Fires: Batteries Not to Blame But Industry Takes Hit Anyway, Energy Storage News, https://www.energy-storage.news/news/koreas-ess-fires-batteries-not-to-blame-but-industry-takes-hit-anyway

2. Cooper, J.J., 2019, Arizona Fire Highlights Challenges for Energy Storage, Associated Press News, https://www.apnews.com/5cd81a81345a40f5b1ac2e5556a68ff7

3. Roth, P.E., Crafts, C.C., Doughty, D.H., et al, 2004, Advanced Technology Development Program for Lithium-Ion Batteries: Thermal Abuse Performance of 18650 Li-Ion Cells, Sandia National Laboratories, p. 6. https://prod-ng.sandia.gov/techlib-noauth/access-control.cgi/2004/040584.pdf

4. Mikolajczak, C., Kahn, M., White, K., et al, 2011, Lithium-Ion Batteries Hazard and Use Assessment, The Fire Protection Research Foundation, p. 97-110, https://www.prba.org/wp-content/uploads/Exponent_Report_for_NFPA_-_20111.pdf

Return to Table of Contents

PROGRAM AREA OVERVIEW: OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

The Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) supports early-stage research and development of energy efficiency and renewable energy technologies that make energy more affordable and that strengthen the reliability, resilience, and security of the U.S. electric grid. DOE resources are focused on early-stage R&D and reflect an increased reliance on the private sector to fund later-stage research, development, and commercialization of energy technologies. EERE emphasizes those energy technologies best positioned to support American energy independence and domestic job-growth.

6. ADVANCED MANUFACTURING

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Advanced Manufacturing Office (AMO) (https://energy.gov/eere/amo) collaborates with industry, small business, universities, and other stakeholders to catalyze research, development and adoption of energy-related advanced manufacturing technologies and practices to drive U.S. energy productivity and economic competitiveness. All technologies proposed under this topic should be able to demonstrate manufacturability.

Applications may be submitted to any one of the subtopics listed below but all applications must:

- Propose a tightly structured program which includes manufacturing-relevant technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Provide evidence that the proposer has relevant manufacturing R&D experience and capability.
- Provide evidence that the proposed technology can be scaled to appropriate manufacturing scale (e.g. widely available, cost-effective inputs, processes providing increased control, speed and throughput)
- Include projections for price and/or performance improvements that are tied to a recent baseline (i.e. Manufacturing Energy Bandwidth Studies and Advanced Manufacturing Technology Assessments (2015) [1] and/or state-of-the-art products or practices);
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis; and
- Justify all performance claims with physics-based theoretical predictions and/or relevant experimental data.

Grant applications are sought in only the following subtopics:

a. Atomic Precision for Energy Efficient and Clean Energy-Related Microelectronics

Atomic precision (AP) for microelectronics means: materials, structures, and devices produced so that atoms are in specified location relative to other atoms and in which there are almost no unintentional defects, missing atoms, extra atoms, or incorrect (impurity) atoms. Thus, while AP microelectronics can include novel 2D materials (e.g. that provide a wide array of electronic properties from metallic to semiconducting to insulating and offer the possibility of engineering devices one atomic layer at a time), approaches are sought that can have precise lateral geometry in a single layer. The combination of high precision and miniaturization means AP microelectronics can be more energy efficient both in operation and in manufacturing yield than traditional microelectronics. In addition, because AP microelectronics can offer significant performance improvements beyond energy efficiency, applications are sought for manufacturing related AP microelectronics that could support higher performance clean energy technologies such as photovoltaics and fuel cells.

Energy efficiency is becoming increasingly important for microelectronics [1] as current fabrication techniques reach the end of the Moore's law miniaturization [2]. Given the urgent need to increase energy efficiency in the near term (less than a decade) this subtopic is focused on AP microelectronics that can be readily integrated with traditional silicon (Si) based electronics. In the decades since atomic precision techniques were first developed for semiconductor devices [3], the initial applications have focused on quantum computing [4]. In this subtopic, however, we seek proposals for AP microelectronics technologies and technology platforms that lead to energy efficient and clean energy related technologies that could potentially transform their prospective industries by dramatically increasing the efficiency and performance of their semiconductor-based products as well as life-cycle energy efficiency and productivity of their manufacturing processes. We also seek proposals to develop tools that are needed to probe, model, and synthesize AP semiconductor devices and materials for energy efficiency and clean energy applications. Since zero defects in microelectronics are implausible at large scales and over the long term, rapid and reliable AP error detection and correction also is needed [5].

All proposals should demonstrate technical merit by including semiconductor manufacturing-relevant technical milestones and cutting-edge, peer-reviewed literature that clearly show how the proposed research design will lead to or support AP materials, structures, and devices that could plausibly be adopted (e.g. applications that can operate at room temperature, and do not require Ultra High Vacuum (UHV)) by the U.S. semiconductor industry in the coming decade. Proposals should provide evidence that the respondent and the proposed research has the experience and capability to design atomically precise microelectronics. For example, proposals could include a graph or chart clearly demonstrating the proposed approach could achieve AP. Responsive images include atomic resolution scanning probe microscope images (STM, AFM etc.) or electron micrographs (TEM, SEM) from the proposer's lab.

Proposers must explain the link between AP enabled by the proposed research and the improved performance in the intended application. Specifically, they should include a description and device modelling showing how their innovation will lead to significant improvements in EERE relevant performance characteristics (e.g. >20% improvement in manufacturing efficiency or ½ quadrillion Btus of annual energy savings or new clean energy). All percentage improvements must be linked to a recent, referenced baseline used by the industry (e.g. comparing to latest available standard**,** showing all units and assumptions). While proposed approaches are not required to specifically meet the above standards, they should demonstrate a path towards meeting them in an industry-relevant time frame**.**

Examples of technology approaches that might be supported under this topic

- Hydrogen Depassivation STM Lithography [6];
- Atomic layer deposition (ALD) [7];
- Atomic layer etching (ALE) [8];
- AP fabrication of carbon nanotube-based (CNT) transistors [9,10];
- Directed self-assembly lithography [11]; or
- Other technologies and techniques to make the above approaches more manufacturable [12, 13].

Examples of applications that could be supported under this topic:

- High performance imaging and characterization tools (e.g. Scanning Probe Microscopes) that specifically enable progress towards manufacturing AP microelectronics;

Return to Table of Contents

- Precise coatings for fuel cells, solar cells, batteries, catalytic surfaces, and membranes [14];
- Low power transistors and other electronics that use quantum effects;
- Sensor (especially with actuator/control) technologies for energy efficiency applications (electronic, photonic, and plasmonic);
- Flexible devices for light detection, emission, and photovoltaics; or
- Error detection and correction methods [5] for AP microelectronics

Phase I proposal should include experimental testing of key aspects of the approach; i.e. it can't be just a proposal for a study.

Questions – Contact: Tina Kaarsberg, tina.kaarsberg@ee.doe.gov

b. Sensors for Harsh and Corrosive Environments

Harsh and corrosive environments encountered in industry include oil, gas, and geothermal well drilling and production, as well as CO_2 gas sequestration applications, facing underground conditions with pressures reaching 20,000 pounds per square inch (psi), temperatures up to 1200°C in corrosive environments exacerbated in deep sea corrosive conditions. Pressure, temperature, composition, and flow rates need to be measured to monitor and control the operation and although candidate materials already exist, suitable sensors that can withstand these conditions are not generally available. Many process industries such as petroleum, chemical, and mining, as well as gas turbines, face similar challenges in process variable measurement and control. This subtopic solicits grant applications for innovation research in new sensor materials and sensor designs, both wired and wireless, with applications to harsh environments encountered in (specified) industries and manufacturing operations. Grant applications for innovative wide area network configuration research are also solicited. Targeted end uses of new sensors and configurations must be specified in the grant application, and these may include any industrial or manufacturing applications where harsh and corrosive or both conditions are encountered. Partnerships with sensor manufacturers, technology end users, and suppliers are strongly encouraged to ensure high probability of commercial success of SBIR R&D. This subtopic is restricted to terrestrial and undersea industrial applications only – and aerospace sensor research and development is specifically excluded.

Areas of interest within this subtopic are as follows:

i. Innovations in materials and configurations of sensors applied in harsh and corrosive environments: Grant applications for innovation research in new materials to be used to construct sensors, as well as new sensor configurations for applications to measurement and control within harsh and corrosive environments, are solicited. Properties of materials selected for investigation within this area of interest should exceed material properties commercially used in harsh environment sensor construction in terms of expected longevity, response to variable to be measured, and availability. Manufacturing constraints of new sensor materials should also be considered. Innovative sensor configurations for measurements within harsh environments are also of interest. Grant applications must address the scientific basis for new sensor materials and configurations and specify the environment and industry(s) where the sensor could be applied. The careful review of relevant scientific and patent literature is strongly urged.

ii. Wide area networks of sensors applied in harsh and corrosive environments: The difficulties of harsh environment sensor networking over wide areas have been discussed, and these difficulties need to be addressed in applications in oil and geothermal wells, undersea applications, and other applications for which sensors need to be distributed. Wired and wireless sensor networks are encumbered by difficulties associated with signal transmission and interference. Grant applications for innovation research that address these difficulties are solicited, and the specific applications of the networks, and the environments they are expected to experience, should be discussed. Relevant data pertaining to the sensor network environment should be included in the application, as well as the proposed means to address the limitations of acquiring data over a distributed network of sensors in harsh environments.

Questions – Contact: Brian Valentine, brian.valentine@ee.doe.gov, or Al Hefner, allen.hefner@ee.doe.gov.

c. Critical Materials Supply Chain Enabling Research

Critical minerals are used in many products important to the U.S. economy and national security. The manufacturing and commercialization of these goods provides employment for American workers and contributes to U.S. economic growth. The U.S. is dependent on foreign sources of critical materials. Of the 35 mineral commodities identified as critical in the list[1] published in the Federal Register by the Secretary of the Interior, the U.S. lacks domestic production of 14 [1] and is more than 50% import-reliant for 31 [2]. This import dependence is a problem when it puts supply chains and U.S. companies and material users at risk. To reduce the nation's vulnerability to disruptions in the supply of critical minerals, the President issued Executive Order 13817, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals* [3].

The Department of Energy (DOE) assesses material criticality based on importance to energy and the potential for supply risk for a range of energy technologies. For many of these energy technologies, there are significant gaps in the domestic supply chain – including downstream processing and manufacturing. A key strategy to address these challenges and barriers is research and development. This SBIR subtopic provides the opportunity to strengthen the domestic critical materials supply chain by reducing (i) dependency of energy technologies on critical materials and (ii) critical materials manufacturing costs through decrease in energy intensity. To be responsive to this subtopic, proposals must:

- Evaluate and quantify how the proposed innovation will contribute to reduced reliance on imported critical materials;
- Describe research and development (R&D) that is directly relevant to the manufacturing of energy technologies, with an emphasis on clean energy technologies;
- Provide evidence that the proposed innovation is cost-competitive and scalable such that it could be manufactured domestically;
- Advance the state of the art and demonstrate improvement relative to a defined baseline;
- Provide evidence that the proposer has the relevant experience and capability for the manufacturing process and energy technology being addressed; and
- Not be duplicative of existing efforts at the Critical Materials Institute, a DOE Energy Innovation Hub funded by the Office of Energy Efficiency and Renewable Energy [4]

Proposals are encouraged to address, but not limited to the following areas of interest:

i. Reduction of Critical Materials in Energy Technologies

The rapidly growing deployment of energy technologies that are dependent on critical materials, such as wind turbines and electric vehicles (EVs), could lead to imbalances of supply and demand

[1] Aluminum (bauxite), antimony, arsenic, barite, beryllium, bismuth, cesium, chromium, cobalt, fluorspar, gallium, germanium, graphite (natural), hafnium, helium, indium, lithium, magnesium, manganese, niobium, platinum group metals, potash, the rare earth elements group, rhenium, rubidium, scandium, strontium, tantalum, tellurium, tin, titanium, tungsten, uranium, vanadium, and zirconium

for key materials. For example, high-torque wind turbines that employ permanent magnet in direct-drive generators to convert mechanical to electrical energy require up to 600 kg/MW of neodymium-iron-boron (NdFeB) magnets. Reduced dependence on critical materials in energy technologies can reduce supply risk and materials costs for downstream manufacturers.

Responsive proposals to this area of interest can include those that seek to significantly reduce critical materials content in energy technologies described in the table below. For example, proposals for reduction of critical materials content in NdFeB magnets should have an upper limit of 20% total Nd/Pr content by 2030 with Dy content not exceeding 1%. Gallium (Ga) content in light-emitting diodes (LEDs) should be less than 35,000 kg/teralumen by 2030. In addition, proposals to reduce Bismuth (Bi) in bearings cannot propose lead (Pb) as the means to reduce or replace Bi.

Critical materials in manufacturing of selected energy technologies [5-6].

Application	**Wind**	**Vehicles**			**Lighting**	**Manufacturing & Mining**	
Technology	Magnets	Magnets	Catalytic Converters	Light-weighting	LEDS	Tooling	Bearings
Bismuth (Bi)							
Cerium (Ce)							
Cobalt (Co)							
Dysprosium (Dy)							
Gallium (Ga)							
Magnesium (Mg)							
Neodymium (Nd)							
Praseodymium (Pr)							
Samarium (Sm)							
Tungsten (W)							

Proposals will be considered non-responsive to this area of interest if they:

- Target reduction of critical materials (including, but not limited to, cobalt, lithium, nickel) in batteries
- Propose a system that completely substitutes for any critical materials dependent technology

ii. Energy Efficient Manufacturing of Critical Materials

The U.S. currently lacks downstream domestic processing and manufacturing capabilities across the critical materials supply chain. Thus, even if domestic production of critical materials is increased, this puts the U.S. at risk for supply disruption, by shifting import-reliance further down the supply chain. For example, in the supply chain for NdFeB magnets, there is currently no domestic processing of rare earth oxides to rare earth metals and alloy, nor domestic manufacturing of NdFeB magnets. This makes domestic manufacturers of direct-drive wind turbines and electric vehicles dependent on foreign sources for NdFeB magnets and reduces U.S. competitiveness in manufacturing.

Reducing energy consumption through investment in advanced processes and technologies can enable domestic manufacturing competitiveness because reduced manufacturing costs through reductions in energy intensity can help offset materials costs in critical material-dependent energy technologies. For example, there is a R&D opportunity for 184 BBtu of energy savings in the manufacturing of magnesium alloys for lightweighting [7].

Proposals in this area of interest are encouraged to increase energy efficiency by targeting reduction of energy intensity of processing and manufacturing of critical materials or critical components for energy technologies, including:

- Manufacturing of gap magnets (energy product ranging from 10 to 20 MGOe);
- Manufacturing of magnesium-based alloys for vehicle lightweighting; and
- Processes to recycle or recover critical materials from end-of-life products.

Proposals must include analysis to demonstrate that the improvements in energy efficiency of processing and manufacturing of critical materials represent a 10% improvement in cost-competitiveness relative to a defined baseline. Cost-competitiveness analyses must consider a complete life-cycle including environmental costs. Improvement in energy efficiency may be achieved by automation of processes, additive manufacturing, reduction of processing temperatures, or other proposed innovations.

Questions – Contact: Helena Khazdozian, Helena.khazdozian@ee.doe.gov

d. Water Desalination: Cost-effective Energy-Recovery for Modular Desalination Systems

Water is a critical resource for human health, economic growth, and agricultural productivity. The United States has historically benefitted from access to low-cost water supplies, but stress on freshwater supplies is threatening U.S. economic competitiveness and water security. Flows of energy and water are intrinsically interconnected, in large part due to the characteristics and properties of water that make it so useful for producing energy and the energy requirements to treat and distribute water for human use.

In October 2018, The Water Security Grand Challenge (WSGC) was announced. The WSGC is a White House initiated, U.S. Department of Energy led framework to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water. Using a coordinated suite of prizes, competitions, early-stage research and development, and other programs, the WSGC has set the five goals for the United States to reach by 2030 (https://www.energy.gov/eere/water-security-grand-challenge).

- Goal 1: Launch desalination technologies that deliver cost-competitive clean water.
- Goal 2: Transform the energy sector's produced water from a waste to a resource.
- Goal 3: Achieve near-zero water impact for new thermoelectric power plants, and significantly lower freshwater use intensity within the existing fleet.
- Goal 4: Double resource recovery from municipal wastewater.
- Goal 5: Develop small, modular energy-water systems for urban, rural, tribal, national security, and disaster response settings.

Small, modular desalination systems, such as the energy-water systems under development as part of Goal 5 of the WSGC have the potential to serve areas where energy and/or clean water is scarce, expensive, or challenging to obtain, such as islands, rural areas, and communities affected by a disaster. However, innovations are needed to improve the specific energy consumption of these small, modular systems and improve their overall cost-effectiveness. Small, modular systems being developed under the WSGC vary in scale, but generally fall into three categories that proposals should respond to at least one:

- 100-500 m^3 per day of potable water;
- 10-100 m^3 per day of potable water; and
- Less than 10 m^3 per day of potable water.

Energy recovery devices (ERDs) have contributed to the significant reduction in energy consumption for large scale reverse osmosis (RO) seawater desalination systems. ERDs reduce the power required to drive the high-pressure pumps in the RO process by transferring energy/pressure from the brine reject stream back to the source water stream [2]. However, commercially available ERDs do not exist in the flow ranges and low weights required for small, modular desalination systems. Therefore, affordable ERDs need to be developed to reduce power consumption in small, modular desalination systems.

This subtopic is focused on innovations that improve the efficiency of ERDs for desalination systems in one or more of the three categories listed above. ERD innovations that integrate renewable energy technologies, such as some concepts under development as part of the WSGC for Solar Desalination Prize and Waves to Water Prize, are of interest.

Proposals must:

- Identify an innovative ERD technology that can be used to recover lost energy in the brine waste stream generated from reverse osmosis desalination of brackish or seawater;
- Address ERDs that are able to operate:
  - using concentrated salt water up to 55,000 ppm,
  - at pressures up to 1200 psi,
  - with flow rates that fit within at least one of the three system design categories listed above, and
  - that could improve over current commercial efficiencies;
- Include a preliminary cost analysis;
- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a recent baseline;
- Explicitly and thoroughly differentiate the proposed ERG innovation with respect to the latest existing commercially available products or solutions;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Proposals should address how the ERD innovation will improve the lifecycle energy efficiency and production costs per m^3 of water for small, modular seawater or brackish water desalination systems, particularly those using renewable energy in one or more of the three categories listed above. The goal of SBIR Phase I would be to demonstrate the feasibility of the ERD to improve energy efficiency and costs using data generated in a laboratory setting and through modeling system costs and operations. Other Phase I objectives include completion of a conceptual design for an ERD prototype (to be demonstrated in Phase II) that when combined with appropriately sized modular desalination system equipment, improves the techno-economics and is suitable for use for a range of small, modular desalination system designs.

Questions – Contact: Melissa Klembara, melissa.klembara@ee.doe.gov

References:

1. Energy Analysis, Data & Reports, https://www.energy.gov/eere/amo/energy-analysis-data-and-reports

References: Subtopic a:

1. U.S. DOE, Office of Science, Report on October 2018 BES BRN Workshop for Microelectronics, 2019, https://science.osti.gov/-/media/bes/pdf/reports/2019/BRN_Microelectronics_rpt.pdf

2. Semiconductor Industry Association, 2015, Rebooting the IT Revolution: A Call to Action, https://www.semiconductors.org/resources/rebooting-the-it-revolution-a-call-to-action-2/

3. Lyding, J.W., Shen, T.-C., Hubacek, J.S., et al, 2010 (1994), Nanoscale Patterning and Oxidation of H-passivated Si (100)-2 £ 1 Surfaces with an Ultrahigh-vacuum Scanning Tunneling Microscope, Applied Physics Letters, 64, https://doi.org/10.1063/1.111722

4. Simmons, M.Y., Schofield, S.R., O'Brien, J.L., et al, 2003, Towards the Atomic-scale Fabrication of a Silicon-based Solid-state Quantum Computer. Surface Science, 532–535, 1209–1218, http://adsabs.harvard.edu/abs/2003SurSc.532.1209S

5. Achal, R., Rashidi, M., Croshaw, J., et al, 2018, Lithography for Robust and Editable Atomic-scale Silicon Devices and Memories, Nature Communications, 2778, https://www.nature.com/articles/s41467-018-05171-y

6. Owen, J.G., Ballard, J.B., Randall, J.N., Alexander, J., et al, 2011, Patterned Atomic Layer Epitaxy of Si/Si(001): H, Journal of Vacuum Science & Technology, B 29, 06F201, https://doi.org/10.1116/1.3628673

7. Oehrlein, G.S., et al, 2015, Atomic Layer Etching at the Tipping Point: An Overview, ECS Journal of Solid-State Science and Technology, 4 (6) N5041-N5053, N5041, https://www.researchgate.net/publication/284705874_Atomic_Layer_Etching_at_the_Tipping_Point_An_Overview

8. Skere, T., Pascher, N., Garnier, A., et al, 2018, CMOS Platform for Atomic-scale Device Fabrication, Nanotechnology, 29, 435302, CMOS Platform for Atomic-scale Device Fabrication, Nanotechnology, 29, https://arxiv.org/abs/1910.00718

9. Sanchez Esqueda, I., Yan, X. Rutherglen, C., et al, 2018, Aligned Carbon Nanotube Synaptic Transistors for Large-Scale Neuromorphic Computing, ACS Nano, 12, https://pubs.acs.org/doi/10.1021/acsnano.8b03831

10. Suh, H.S., Kim, D.O., Moni, P., et al, 2017, Sub-10-nm Patterning via Directed Self-assembly of Block Copolymer Films with a Vapour-phase Deposited Topcoat, Nature Nanotechnology, 12, 575–581, https://www.nature.com/articles/nnano.2017.34

11. Thuaire, A., Reynaud, P., Brun, C., et al, 2016, Innovative Solutions for the Nanoscale Packaging of Silicon-Based and Biological Nanowires: Development of a Generic Characterization and Integration Platform, IBM EEE Transactions on Components, Packaging and Manufacturing Technology, Vol. 6, No. 12, https://ieeexplore.ieee.org/document/7784812

12. Prakesh, P., Sundaram, K.M., Bennet, M.A., 2018, A Review on Carbon Nanotube Field Effect Transistors (CNTFET) for Ultra-low Power Applications. Renewable and Sustainable Energy Reviews, Vol 89, https://doi.org/10.1016/j.rser.2018.03.021

13. Cremers, V, Puurunen, R., Dendooven, J., 2019, Conformality in Atomic Layer Deposition: Current Status Overview of Analysis and Modelling, Applied Physics Reviews, Review 6, 021302, https://doi.org/10.1063/1.5060967

14. Pavliček, N., Majzik, Z., Meyer, G., et al, 2017, L. Tip-induced Passivation of Dangling Bonds on Hydrogenated Si (100)-2 × 1, Applied Physics Letters, Letter 111, 53104, https://aip.scitation.org/doi/10.1063/1.4989749

References: Subtopic b:

1. Ngo, H.D., 2016, Sensors for Harsh Environments, MDPI Open Access Journals, https://www.mdpi.com/journal/sensors/special_issues/SHE#editors

2. Middelburg, L.M., Van Driel, W.D., Zhang, Q., 2019, From Si Towards SiC Technology for Harsh Environment Sensing, Sensor System Simulations, Springer Nature, Switzerland, p. 1-15, https://link.springer.com/book/10.1007/978-3-030-16577-2#toc

3. 2019, Sponsored Content: Pressure Sensors that Meet Harsh Environment Requirements, Electronics Weekly, https://www.electronicsweekly.com/news/products/sensors-products/sponsored-content-pressure-sensors-meet-harsh-environment-requirements-2019-05/

References: Subtopic c:

1. U.S. Department of the Interior, 2018, U.S. Geological Survey, Mineral Commodity Summaries 2018, https://doi.org/10.3133/70194932

2. U.S. Department of the Interior, 2018, Final List of Critical Minerals 2018, Federal Register: The Daily Journal of the United States Government, 83 FR 23295, https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018

3. Executive Office of the President, 2017, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Materials, Federal Register: The Daily Journal of the United States Government, 82 FR 60835, https://www.federalregister.gov/documents/2017/12/26/2017-27899/a-federal-strategy-to-ensure-secure-and-reliable-supplies-of-critical-minerals

4. Complete Project List, Critical Materials Institute, https://cmi.ameslab.gov/project-list

5. U.S. Department of Energy, 2011, Critical Materials Strategy, https://www.energy.gov/policy/downloads/2011-critical-materials-strategy

6. U.S. Department of Energy, 2015, Innovating Clean Energy Technologies in Advanced Manufacturing, Quadrennial Technology Review, Chapter 6, https://www.energy.gov/sites/prod/files/2015/12/f27/QTR2015-6F-Critical-Materials.pdf

7. U.S. Department of Energy, 2017, Bandwidth Study on Energy Use and Potential Energy Saving Opportunities in U.S. Magnesium Manufacturing, Advanced Manufacturing Office, https://www.energy.gov/sites/prod/files/2019/05/f62/Magnesium_bandwidth_study_2017.pdf

Return to Table of Contents

References: Subtopic d:

1. U.S. Department of Energy, Water Security Grand Challenge, https://www.energy.gov/eere/water-security-grand-challenge

2. Stover, R., Andrews, B., 2012, Isobaric Energy-Recovery Devices: Past, Present, and Future, DOI: 10.1179/ida.2012.4.1.38, https://www.researchgate.net/publication/272252091_Isobaric_Energy-Recovery_Devices_Past_Present_and_Future

7. BIOENERGY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Bioenergy Technologies Office (BETO) has a mission to help transform the nation's renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower. BETO is focused on forming partnerships with key stakeholders to develop technologies for advanced biofuels production from lignocellulosic and algal biomass as well as waste resources.

All applications to this topic must:

- Include projections for price and/or performance improvements that are tied to a baseline (i.e. MYPP and/or state of the art products or practices);
- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis;
- Provide a path to scale up in potential Phase II follow on work;
- Fully justify all performance claims with thoughtful theoretical predictions or experimental data;
- Be based on sound scientific principles (i.e. abides by the law of thermodynamics).

Grant applications are sought in the following subtopics:

a. Novel Approaches for Monitoring and Valorizing Bioenergy-Derived Ecosystem Services

The Bioenergy Technologies Office pursues multiple strategies to reduce the cost of biofuels to less than $3/gge. One strategy that has not been fully developed is the concept of valorizing ecosystem services provided by bioenergy. These ecosystem services can include erosion control, runoff prevention, reduced nutrient and chemical loading, carbon sequestration, pollinator/wildlife habitat, and enhanced biodiversity.

In order for ecosystem services to be integrated into the bioenergy value chain, reliable approaches are needed to quantify the magnitude of these benefits as well as to monitor and verify that these benefits occur. Furthermore, these methods must be low-cost and practical to be widely adopted.
This topic seeks proposals to develop innovative technologies for monitoring, validating, and/or valorizing ecosystem services of bioenergy in a manner that is low-cost and directly applicable to existing or emerging economic opportunities (e.g., environmental markets). These economic opportunities could include (but are not limited to) nutrient and water quality trading, voluntary carbon markets, or

institutions financially supporting ecosystem services to meet their sustainability goals (e.g. corporate social responsibility initiatives).

General requirements:

- Projects must advance the capabilities for monitoring, validating, and/or valorizing the ecosystem services of biomass, bioenergy, or bioproducts so that producers could be compensated for the benefits provided.
- Projects must align their approach with at least one existing or emerging economic opportunity (e.g., environmental market) by which producers could receive economic value for the ecosystem service(s) generated.
- Proposed systems must pertain to lignocellulosic or algal biomass that when produced or harvested provides environmental benefits. Biomass types *not* of interest include plant material generally intended for use as food or animal feed, oilseed crops, or agricultural or forestry residues.

Questions – Contact: Kristen Johnson, kristen.johnson@ee.doe.gov

b. Bioenergy Feedstock Engineering Incubator

BETO's Feedstock Supply and Logistics subtopic, "Bioenergy Feedstock Engineering Incubator" is intended to identify potentially impactful ideas that are not meaningfully addressed in the subprogram's current project portfolio. The subtopic will be open to all applications that propose the development of technologies that facilitate the goals of the Feedstock Supply and Logistics R&D subprogram. Applicants can review the 2019 Peer Review [1] and 2017 Peer Review [2] reports to identify what R&D has already been funded in the portfolio, and the Multi Year Plan [3] to identify the programs goals.

The scope for this subtopic is intentionally broad. Examples of proposals that fit this subtopic include:

- Improved testing of potential raw materials for energy content, fiber content, non-combustible minerals, and other trace materials such as chlorine, mercury, and sulfur.
- Methods for targeted removal of contaminants from feedstock streams
- Novel approaches for creating feedstock supply chains for renewable carbon sources not typically of focus of the Feedstock Supply and Logistics Program (waste streams and re-useable carbon sources such as the non-recyclable organic portion of municipal solid waste, biosolids, sludges, waste food, plastics, CO_2, and manure slurries).
- Novel approaches for creating feedstock supply chains from ocean-based plastics; specifically, could include methods of sorting, separating, and recycling ocean plastic into feedstock and/or quantifying the quality of ocean plastic streams in terms of constituent elements.

Applicants should clearly describe how their project will be aligned with the Feedstock Supply and Logistics' goals or how success of their project will facilitate the success of performers in BETO's feedstocks portfolio.

Applications specifically not of interest:

- Applications that propose to conduct R&D that was the primary focus of previous funding opportunities. Examples of work supported by previous funding opportunities are:
    - Application of landscape design approaches to integrate cellulosic feedstock production into existing agricultural and forestry systems while maintaining or enhancing environmental and socio-economic sustainability including ecosystem services and food, feed, and fiber production.

Return to Table of Contents

  - Generating scientific information on new varieties/cultivars of energy crops, specifically, the degree to which they show performance improvements relative to better characterized predecessor varieties, how well adapted they are across regions, whether they may be more cost-effective to produce, and whether they can be shown to be more sustainable relative to a check variety and/or traditional cropping/pasture systems.
  - Fractionation methods for corn stover and pine--research on how the individual components/tissue fractions affect variability in feedstock specifications
- Applications that propose to use plant material that is generally intended for use as food or animal feed.

Questions – Contact: Mark Elless, mark.elless@ee.doe.gov

References:

1. U.S. Department of Energy, 2019, 2019 Project Peer Review, Bioenergy Technologies Office, https://www.energy.gov/eere/bioenergy/peer-review-2019

2. U.S. Department of Energy, 2017, Peer Review 2017, Bioenergy Technologies Office, https://www.energy.gov/eere/bioenergy/peer-review-2017

3. U.S. Department of Energy, 2016, Multi-Year Program Plan, Bioenergy Technologies Office, https://www.energy.gov/sites/prod/files/2016/07/f33/mypp_march2016.pdf

8. BUILDINGS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Residential and commercial buildings account for approximately 40% of the nation's total energy demand [1] and 75% of electricity use [2], resulting in an annual national energy bill totaling roughly $415 billion [3]. The U.S. Department of Energy's Building Technologies Office (BTO) (http://energy.gov/eere/buildings) is working in partnership with industry, academia, national laboratories, and other stakeholders to develop innovative, cost-effective, energy saving technologies that could lead to a significant reduction in building energy consumption and enable sophisticated interactions between buildings and the power grid. The rapid development of next-generation building technologies are vital to advance building systems and components that are cost-competitive in the market, to enable deep energy use reduction and lead to the creation of new business and industries. Widespread adoption of existing energy-efficient building technologies–and the introduction and use of new technologies–can reduce energy use in residential and commercial buildings by 50%, saving over $200 billion annually and reducing U.S energy-related greenhouse gas (GHG) emissions by roughly 20% compared to 2010 levels [4].

Applications may be submitted to any one of the subtopics listed below but all applications must:

- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for cost and/or performance improvements that are tied to clearly defined baseline and/or state of the art products or practices;
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;

- Include an estimate of energy savings and/or demand flexibility impact as well as a preliminary cost analysis;
- Justify all performance claims with theoretical predictions and/or experimental data.

All successful proposals must demonstrate that the enabling research completed under this effort will succeed in producing the predicted performance advancement and reduction of technical risk required to move to successive stages of research. The proposed Phase I effort should be designed to retire significant technical risk and make proof of principle of the proposed approach. Phase II may continue to develop the approach, but the fundamental question of penultimate price and performance of the proposed innovation should be well documented and clear in the Phase II proposal.

Grant applications are sought in the following subtopics:

a. Advanced Robotics, Tools, and Approaches for Retrofitting of Existing Buildings

BTO is seeking proposals that use advanced robotics, augmented reality, and other novel automation technologies and approaches to advance the state of the art for affordable, fast, and non-invasive energy retrofits of existing residential and commercial buildings.

Although available retrofit technologies and approaches could cut building energy use in half, only a small portion of existing buildings undergo efficiency retrofits [1, 2]. One of the main reasons for this is that available building efficiency products and processes can be particularly disruptive in existing, occupied buildings which, understandably, often leads to a reluctance to adopt them. Furthermore, unlike energy-using equipment that is replaced periodically due to failure or obsolescence, building envelopes are much less frequently altered; and, more common changes, such as reroofing or residing, rarely result in improved energy performance. Existing retrofit approaches also rarely address moisture and vapor flow control layers, thus increasing the risk of moisture, comfort, and durability failures. To tap into the potential that buildings hold in terms of deep energy savings while improving health and durability, home and building owners need new alternatives for improving building envelope performance – options that are affordable and much less disruptive.

The expected output of a successful Phase I project is a design and proof of concept prototype of a transformational retrofit technology or approach that addresses the main barriers to current energy retrofits. Applicants are encouraged to identify a small group of relevant partners to help provide feedback and demonstrate the utility and relevance of the retrofit technology and approach. Successful Phase I projects should be ready to apply for Phase II awards that enable testing and field validation of the retrofit solution developed in Phase I. Applicants should explain how the proposed technology and approach reduces disruption to occupants through shortened installation times and method of installation, delivers significant energy savings, addresses the four building science control layers of moisture, vapor, air, and thermal, and improves the commercial and economic viability of the retrofit solution.

Interdisciplinary teams of investigators are invited to submit proposals for the development of innovative, out-of-the-box retrofit solutions utilizing advanced robotics, tools, and approaches in the following areas:

- Breakthrough low-cost approaches for effective moisture and vapor control layers, air sealing, and insulating of existing residential or commercial buildings, particularly in areas unattainable or unaffordable with today’s approaches, including the addition of continuous control layers and insulation upon cladding replacement;
- Novel hardware and software tools and approaches for improving onsite installation quality and performance, as well as significantly improving the speed of retrofits;

- Any other transformational innovations that further the efficiency and efficacy of building envelopes of existing buildings or greatly improve the affordability of whole building energy efficiency retrofits.

Questions – Contact: Sven Mumme, sven.mumme@ee.doe.gov

b. Innovative Building Energy Rating Delivery Models

BTO is seeking proposals that use new and emerging approaches to generate and leverage standardized asset-level data to advance the state of the art for data-driven building technology projects at either the individual building or building stock scale across both commercial and residential sectors. In order to distill the large volume of asset data collected in either a residential or commercial audit, asset ratings tools, such as BTO's Home Energy Score™ and Building Energy Asset Score, have been developed to provide consistently derived metrics, including a single score that conveys the modeled efficiency of the building. These tools simplify the data collection process for an audit and have built-in quality control mechanisms to ensure consistent information is submitted from the evaluation of the home, multifamily, or commercial building. Home Energy Score then goes further to provide access to data via an application programming interface (API), and a report detailing energy use by fuel type. Asset Score provides a BuildingSync XML file, an OpenStudio model, and a report detailing energy use by end use and by space type for commercial and multifamily buildings. Innovative approaches are needed to increase the availability of this type of standardized asset-level data and understand the impact the information has on increasing the efficiency of residential and commercial building stocks.

Home Energy Score and Asset Score enable building owners and operators to make more informed decisions about how buildings use energy and assess potential for energy efficiency improvements. They also provide a mechanism for valuing building energy features in real estate transaction processes. However, these tools are most valuable when widely used and allow easy comparison of the efficiency of different properties. Innovative delivery models for increasing availability of commercial and residential asset-level data will present compelling new opportunities for the use of these tools, channels for dissemination of energy asset information, and promote standardization of this data in line with BTO best practices and taxonomies. In addition to developing quicker, low-cost delivery methods, proposals may also seek to augment the utility of these tools by incorporating other services or information to enhance the research value of these asset-level data sets.

The expected output of a successful Phase I project is a pilot program demonstrating low-cost delivery of Home Energy Score and/or Asset Score to an identified market and measurable uptake of that information in decision-making processes to deliver energy efficiency improvements. Applicants are encouraged to identify a small group of relevant partners to help provide feedback and encourage innovation to help ensure the proposed approach is scalable and useful in informing decisions and encouraging building efficiency improvements. Successful Phase I projects should be ready to apply for Phase II awards that enable rapid scaling, testing, and data-driven validation of the model developed in Phase I.

Proposals should focus on the Home Energy Score and/or Asset Score tools for the core of the delivery model; however, other open source BTO-funded tools such as EnergyPlus, OpenStudio, or the Standard Energy Efficiency Data (SEED) Platform may be considered as well. Proposals are encouraged to leverage existing open data standards and exchange schema, such as the Building Energy Data Exchange Specification (BEDES), BuildingSync XML, or HPXML where relevant.

Questions – Contact: Madeline Salzman, madeline.salzman@ee.doe.gov

c. Efficient, Resilient Building Technologies

The U.S. Department of Energy's Building Technologies Office (BTO) is seeking to develop technologies that provide the co-benefit of increased energy resilience in addition to improved energy efficiency. Energy saving measures are well suited to provide energy resiliency benefits [1]. Systems that are still able to perform critical building functions in limited power states can minimize the effect of power disruptions on building occupants. Techniques such as tapping into storage or other energy sources [2], possessing passive operation capabilities, or making use of alternative energy and mass transfer management strategies are examples of approaches that may potentially improve energy resilience.

Proposals should present ways in which new controls, materials, or systems can be utilized to promote energy resilience within a building. Energy resilience refers to the ability of energy-related systems of a building or community of buildings to predict and prepare for, withstand, recover rapidly from, and adapt to major or unanticipated disruptions. Emphasis should be placed on equipment and controls that provide thermal loads within the building. This includes materials and other engineering approaches and solutions that can dynamically control heat, moisture, or other energy/mass fluxes between the ambient and the conditioned space. Applicants should present a work plan that includes the design of a device or system that will bolster energy resilience. A critical component of the system must be chosen for proof-of-concept demonstration.

Proposals should clearly identify the following:

- Energy saving potential of the proposed concept;
- The hazard scenario the concept will address (e.g. low or no power);
- What building function(s) the proposed concept will make more resilient (thermal comfort, ventilation, etc.);
- How long the concept will sustain the identified building function(s) within acceptable levels for the occupant after hazard event occurs;
- State assumptions for acceptable levels of operation;
- Which component of the solution will be fabricated for proof-of-concept.

Questions – Contact: Nelson James, nelson.james@ee.doe.gov

d. Novel Materials and Processes for Solid-State Lighting

BTO seeks to accelerate the development of next-generation lighting, and supports foundational solid-state lighting (SSL) R&D. This early-stage R&D advances the understanding of underlying physical phenomena, explores new technical and fabrication approaches, and develops an understanding of application requirements that improve lighting effectiveness. Advancements in SSL technology have highlighted gaps in understanding at not only the material-device level, but also at the lighting science level. Research in these areas will enable the next level of performance advancements for SSL. Ongoing innovation and breakthroughs in materials, devices, advanced fabrication processes, and integration are needed to realize the full potential of the technology. In addition, at the lighting science level, the SSL technology platform raises new questions as to the effectiveness of the quality, delivery, and control of lighting.

SSL, particularly light emitting diode (LED) technology, is on course to become the dominant technology across all lighting applications. The luminous efficacy, as measured in lumens per watt (lm/W), of SSL continues to advance toward the practical limit of 255 lm/W for phosphor-converted LED architectures and the ultimate theoretical limit of 325 lm/W for direct emitting architectures. Beyond LEDs, advancements in organic light emitting diode (OLED) technology are also needed to achieve efficiency targets. OLED lighting offers an intriguing performance and production counterpoint to LED lighting. By its very nature, OLED lighting is diffuse. Every other lighting technology, including LEDs, requires optical diffusion to protect occupants from the bright light source's glare. Significant performance and cost barriers remain for OLED lighting. OLED efficacy greatly lags LED efficacy at approximately 90 lm/W with a target of 190 lm/W. However, there may be application-specific energy efficiency advantages. OLED lighting technology needs ongoing R&D to improve efficiency at the material, device, and light extraction levels. Additionally, these advancements in efficiency will have a direct impact on affordability and reliability.

Suggested areas of research are detailed below:

- Additive manufacturing for lighting products that enable reduced part count, more efficient production, on demand semi-custom production, and novel form factors for lighting products. The topic is applicable for large area lighting roll-to-roll processes as well as LED components.
- Concepts and products for improved lighting application efficiency, including development lighting products that more efficiently deliver lighting to the target, deliver a more suitable spectrum to the target, and/or deliver a more suitable light intensity for the application. The scope also includes software modeling tools that incorporate spectral power distribution of light sources and reflective spectra of interior surfaces in addition to lighting and daylighting optical distribution. Such software should enable advanced lighting design as well as guide development of novel lighting layouts, product form factors, and optical distributions.
- Advanced lighting technologies with state-of-the-art performance, with novel form factors that use lower embedded energy materials; with novel electrical or architectural integration concepts that improve efficiency or building resiliency; and/or with light output levels and optical distributions that enable more effective and efficient lighting layouts in a commercial space.
- New electronic components and circuit topologies for SSL drivers that remove at risk components like electrolytic capacitors and MOSFETs and enable smaller form factors, efficient operation across the entire operating range.
- Encapsulation materials, processes and products for OLEDs or LEDs. High temperature encapsulants that extend the LED operating range and/or encapsulants that can be patterned for optical directionality (glass, crystalline materials, and others beyond silicone); thin film encapsulants for OLEDs that achieve low WVTR and are defect free over large areas produced by low cost, high throughput processes.
- Transparent conductors to enable current spreading across large area devices that are smooth, cost-efficient, easily patterned, and compatible with OLED materials and processing.
- Approaches that advance the state of the art in active beam steering for LEDs or OLEDs, including but not limited to microelectromechanical systems (MEMS), liquid crystals.
- Tools and approaches for improving the process and operations of LED wafer-level packaging.
- Research to advance the state of thin, diffuse lighting products with low glare, reduced thermal management requirements, and thin, lightweight and possibly flexible or conformable form factors. Such products can be made with OLEDs, quantum dot (QD) emitters, perovskites, and other novel electroluminescent (EL) emitters; LED arrays (including micro-LED arrays); or LED edge-lit waveguides. Here we are open to proposals that advance the source, panel, and the integrated system level including:
  - Emitters with long lifetime and high efficiency, particularly blue;
  - Device structures designed for stable white light (low voltage, high efficiency across the spectrum);
  - Transparent conductors with low sheet resistance for uniform emission over large areas;

- Light extraction techniques to improve control over the light distribution without sacrificing delivered external quantum efficiency (EQE);
- Device manufacturing and materials improvements for reliable, stable devices;
- Device manufacturing and materials to reduce system cost without sacrificing performance.

Each submitted proposal should address one or more of the areas noted, and the relevant topic(s) should be noted in the proposal. However, these areas should not be considered as distinct topics, and DOE may not award proposals in all areas. The primary benefit of the research proposed must be aligned with the performance targets described in the 2018 Solid-State Lighting R&D Opportunities document.

Questions – Contact: Brian Walker, brian.walker@ee.doe.gov

References:

1. U.S. Department of Energy, 2019, U.S. Energy Information Administration, Monthly Energy Review, Table 2.1, https://www.eia.gov/totalenergy/data/monthly/#consumption

2. U.S. Department of Energy, 2019, U.S. Energy Information Administration, Electric Power Monthly, Table 5.1, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_01

3. U.S. Department of Energy, 2019, U.S. Energy Information Administration, Natural Gas Summary, http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm

4. U.S. Department of Energy, 2019, Building Technologies Office Multi-Year Program Plan: Fiscal Years 2016-2020, Energy Efficiency & Renewable Energy, https://www.energy.gov/sites/prod/files/2016/02/f29/BTO%20Multi-Year%20Program%20Plan%20-%20Final.pdf

References: Subtopic a:

1. Neme, Chris, Gottstein, M., Hamilton, B., 2011, Residential Efficiency Retrofits: A Roadmap for the Future, Regulatory Assistance Project, www.raponline.org/wp-content/uploads/2016/05/rap-neme-residentialefficiencyretrofits-2011-05.pdf

2. Amann, J.T., 2017, Unlocking Ultra-Low Energy Performance in Existing Buildings, American Council for an Energy Efficient Economy, www.aceee.org/white-paper/unlocking-ule-0717.

References: Subtopic c:

1. U.S Department of Energy, The Efficiency-Resilience Nexus, Building Technologies Office, https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Energy-Resilience%20Nexus%20Fact%20Sheet.pdf

2. U.S. Department of Energy, Distributed Energy Resources Disaster Matrix, Building Technologies Office, https://betterbuildingsinitiative.energy.gov/sites/default/files/attachments/DER_Disaster_Impacts_Issue%20Brief.pdf

Return to Table of Contents

9. FUEL CELLS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Fuel Cell Technologies Office (FCTO)[1] is a key component of the Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) portfolio. The central mission of FCTO is to stimulate the U.S. economy and global competitiveness by reducing dependence on foreign oil imports and establishing a domestic power and fuel industry using efficient, reliable clean energy technologies through early stage research and technology development. To achieve this goal, FCTO invests in early-stage, innovative technologies that show promise in harnessing American energy resources safely and efficiently. Fuel cells can address our critical energy challenges in all sectors – commercial, residential, industrial, and transportation.

Fuel cell electric vehicles (FCEVs) using hydrogen can achieve significantly higher efficiencies than combustion engines resulting in overall less energy use. Hydrogen can be produced from diverse domestic resources, such as natural gas, oil, coal, and biomass, as well as from renewables using methods such as direct or indirect water splitting. In addition to transportation applications, hydrogen and fuel cell technologies can also serve stationary applications – i.e. providing responsive back-up power and other electric and fuel distribution services improving energy security and reliability. Thus, fuel cell and hydrogen technologies enable American energy dominance by safely and efficiently harnessing domestic resources.

FCTO addresses key technical challenges for both fuel cells and hydrogen fuels (i.e., hydrogen production, delivery, and storage). Light duty FCEVs are an emerging application for fuel cells that has earned substantial commercial and government interest worldwide due to the superior efficiencies, reductions in petroleum consumption, and reductions in criteria pollutants possible with fuel cells. Recent analyses project that, if DOE cost targets for FCEVs are met, U.S. petroleum consumption can be reduced by over one million barrels per day [3]. FCEVs reduce petroleum consumption by about 95% in comparison to conventional light duty vehicles when the hydrogen is produced from natural gas [2, 3]. The areas identified in this topic will enable progress towards commercializing light duty FCEVs.

Grant applications are sought in the following subtopic. Applications may be submitted to any one of the subtopics listed below but all applications must:

- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a baseline (i.e. MYPP or Roadmap targets and/or state of the art products or practices);
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopics:

a. Production of Low-cost Hydrogen from Off-shore Wind Power

Over the last decade the cost of both wind power and of water electrolysis systems have decreased significantly. The cost of connecting wind farms to the electricity grid is becoming significant fraction of the wind projects capital costs [1], while the cost of power electronics needed for connecting electrolysis stack to the grid power supply approaches 30% of the system capital cost [2]. Direct coupling of a wind turbines with a water electrolysis system can help eliminate these high cost components on both ends of the system. Hydrogen produced by the electrolyzer can then be stored and delivered to remote/on-shore power applications, or further combined with nitrogen or captured CO_2 to produce ammonia or renewable hydrocarbon fuels.

Several projects around the world are developing the technologies directed towards production of hydrogen from wind power:

- In the UK, ITM Power in collaboration with Ørsted and Element Energy is conducting the Gigastack feasibility study to demonstrate the delivery of bulk, low-cost and zero-carbon hydrogen produced through gigawatt scale polymer electrolyte membrane (PEM) electrolysis. The project will develop innovations in the siting and operation of large electrolyzers to exploit synergies with large GW scale renewable energy deployments [3].
- Environmental Resources Management (ERM), also in the UK, is involved in the Dolphyn Green Hydrogen project which is developing production of hydrogen from offshore wind. The project will showcase a floating semi-submersible platform design with an integrated wind turbine, PEM electrolysis and desalination facilities.
- In the North-West of the Netherlands, Duwaal is developing a green hydrogen project to demonstrate a "wind-to-wheel" concept that will involve: (1) integrating hydrogen production with a wind turbine; (2) integrating high-pressure storage, transport, and distribution systems; and (3) operating at least 100 hydrogen powered trucks utilizing the produced hydrogen [4].

Large-scale transmission of renewable power via chemical bonds in the wind-to-hydrogen approach is attractive, especially over long distances, but cost challenges remain. Applications are sought for proposing innovative concepts to enable robust coupling of wind turbines with water electrolysis systems to produce low-cost hydrogen from stranded renewable wind energy resources, such as land-based and especially offshore wind power. Proposals should include a feasibility analysis that clearly addresses the technical challenges associated with integration of a wind turbine with a water electrolysis stack, such as matching the power loads and voltages, managing rapid variation of the turbine power output, allowing for frequent starts and stops, providing required water purity and output hydrogen quality, or ruggedizing and automating systems for remote offshore use. In addition, once the hydrogen is produced at the site, the system may include transport concepts (such as barge transport, pipelines, etc.) to deliver the hydrogen for end use. If hydrogen is used at the remote site as a means of energy storage, rather than transported to point of use, then the proposed system concept must include proven generation (e.g. fuel cell, turbine, etc.) to provide power, at times when wind power is not available. The application should also include a cost analysis to show how the proposed solution will overcome a specific challenge, or challenges to enable low-cost hydrogen production below the $2/kg DOE hydrogen production target [5]. The cost analysis should also address how the overall system cost for the hydrogen-based large-scale transport of energy from stranded wind resources would compare with other options (such as electric transmission lines).

Phase I of the SBIR project is expected to develop a detailed system concept and techno-economic analysis of the proposed solution with a sub-scale demonstration of the proposed concept in the Phase II.

Questions – Contact: Michael Hahn (michael.hahn@ee.doe.gov)

References:

1. Fuel Cell Technologies Office (FCTO) http://energy.gov/eere/fuelcells/fuel-cell-technologies-office

2. Nguyen, T., Ward, J., 2016, Life-Cycle Greenhouse Gas Emissions and Petroleum Use for Current Cars, U.S. Department of Energy Fuel Cell Technologies Office, p. 5, https://www.hydrogen.energy.gov/pdfs/16004_life-cycle_ghg_oil_use_cars.pdf

3. Andress, D., Nguyen, T., Morrison, G., 2016, GHG Emissions and Petroleum Use Reduction from Fuel Cell Deployments, U.S. Department of Energy Fuel Cell Technologies Office, p. 8. https://www.hydrogen.energy.gov/pdfs/16021_ghg_emissions_petroleum_reduction_from_fc.pdf

References: Subtopic a:

1. U.S. Department of Energy, 2018, 2018 Wind Technologies Market Report, Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/sites/prod/files/2019/08/f65/2018%20Wind%20Technologies%20Market%20Report%20FINAL.pdf

2. Mayya, A., Ruth, M., Pivovar, B., 2019, Manufacturing Cost Analysis for Proton Exchange Membrane Water Electrolyzers, National Renewable Energy Laboratory (NREL), https://www.nrel.gov/docs/fy19osti/72740.pdf

3. Markillie, R., 2019, Gigastack Feasibility Study with Orsted, ITM Power, https://www.itm-power.com/news-item/gigastack-feasibility-study-with-orsted

4. Duwaal, Hygro: Enabling Hydrogen from Wind to Wheel, https://hy-gro.net/en/duwaal

5. Satyapal, S., 2019, Hydrogen and Fuel Cell Program Overview, U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, https://www.hydrogen.energy.gov/pdfs/review19/plenary_overview_satyapal_2019.pdf

10.GEOTHERMAL

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Geothermal energy is secure, reliable, flexible, and constant. It continues to be one of America's best choices for low-cost renewable energy in power generation and in direct-use applications for heating and cooling of American homes and businesses. The Geothermal Technologies Office (GTO) focuses on applied research, development, and innovations that will improve the competitiveness of geothermal energy and support the continued expansion of the geothermal industry across the U.S. [1]. Specifically, GTO is focused on significantly increasing geothermal electricity generation and the use of geothermal heat pumps and district heating by 2050 [2]. By adding energy storage capability to geothermal resources, the power produced or offset can be dispatched as necessary based on changing grid conditions, further expanding the usage and utility of geothermal energy. Because deploying advanced geothermal energy storage contribute to grid reliability, flexibility, resilience and security, this technology area also supports DOE's Grid Modernization Initiative [3].

A Phase I application should focus on proof of concept and bench scale testing that are scalable to a subsequent Phase II prototype development. Applications must be responsive to the subtopics below. Any application outside of these areas will not be considered.

Applications must:

- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a baseline (i.e. roadmap targets and/or state of the art products or practices);
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis; and
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopic:

a. Advanced Geothermal Energy Storage

The Advanced Energy Storage Initiative (AESI) [4] in Energy Efficiency and Renewable Energy (EERE) focuses on research and development that improves flexibility and grid services, thereby cost-effectively improving (electric grid) reliability. Geothermal-specific AESI areas include bi-directional energy storage and flexible generation. In this subtopic, GTO solicits innovative research and development projects to enable improved energy storage capability in either direct use applications or at geothermal power plants.

- Bi-Directional Energy Storage:
  This technology area focuses on bi-directional energy storage, or technologies that can absorb, store, and discharge energy that can support grid flexibility or direct end uses, including process heating or space heating for buildings. Proposed technologies could include but are not limited to innovative usage of shallow-earth reservoirs and hybridization of geothermal heat pumps or direct use equipment with other energy sources for purposes of energy storage.

  Technologies funded under this technology area should aim to reduce the cost of utilizing geothermal energy directly to heat and potentially cool large district energy systems with the goal of using little if any grid electricity for heating and cooling. Applicants must include cost, storage, and lifetime targets for the proposed technology that can be benchmarked to comparable state-of-the art applications.

- Flexible Energy Generation:
  This technology area focuses on flexible geothermal generation or geothermal power generation technologies that can enable geothermal power plant curtailment/pause/restart more efficiently than is currently possible. Improved flexibility of geothermal power plants can provide electric grid support during periods of changing electricity production or demand. Proposed technologies could include but are not limited to hybridization of geothermal power plants with other renewable energy sources, or non-battery based energy storage technologies.

  The proposed technology must include metrics relating the degree to which geothermal power generation increases or decreases on demand and response time improvement relative to the state-of-the art geothermal power generation technology. Metrics demonstrating how the proposed technology can increase grid stability and reliability are also encouraged.

Both technology areas are solely focused on advanced geothermal energy storage; innovation into battery-based energy storage technologies, or other types of standard operational efficiency improvements will be deemed non-responsive.

[Return to Table of Contents](#)

Questions – Contact: William Vandermeer, william.vandermeer@ee.doe.gov

References:

1. U.S. Department of Energy Geothermal Technologies Office, https://energy.gov/eere/geothermal

2. U.S. Department of Energy, GeoVision: Harnessing the Heat Beneath our Feet, Geothermal Technologies Office, https://www.energy.gov/eere/geothermal/geovision

3. U.S. Department of Energy, Grid Modernization Initiative, https://www.energy.gov/grid-modernization-initiative

4. U.S Department of Energy, 2019, Advanced Energy Storage Initiative, U.S. Department of Energy FY2020 Congressional Budget Request, https://www.energy.gov/sites/prod/files/2019/04/f61/doe-fy2020-budget-volume-3-Part-2.pdf

11. SOLAR

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Solar Energy Technologies Office (SETO)[1] is the primary office within the U.S. Department of Energy (DOE) that funds innovations in solar power. The office is housed within the Office of Energy Efficiency and Renewable Energy (EERE). SETO supports early-stage research and development in the technology areas of photovoltaics, concentrating solar-thermal power, and systems integration with the goal of improving the affordability, reliability, and performance of solar technologies on the grid. The office invests in innovative research efforts that securely integrate more solar energy into the grid, enhance the use and storage of solar energy, and lower solar electricity costs.

In September 2017 the office announced that its goal to make solar electricity costs competitive with other generation sources by 2020, without subsidies, had been met three years ahead of schedule for utility-scale photovoltaic solar systems[2]. The office will continue to work to lower the cost of solar (photovoltaics and concentrated solar power) energy and has established a goal to halve the cost of solar energy by 2030[3]. With the dramatic reduction in the cost of solar, installations have soared, creating new challenges and opportunities for the electricity grid. To account for these changing needs, the office is also focusing on solar energy research and development efforts that help address the nation's critical energy challenges: grid reliability, resilience, and affordability.

SETO commercialization programs

Historically SETO has supported the commercialization of solar innovations through a series of Funding Opportunity Announcements and other funding programs that relate to one another but have their own unique attributes. Specifically:

- The American Made Challenges Solar Prize[4] is a competition for the best idea and action plan, and there is no requirement to establish a company to enter the competition;
- The SBIR/STTR program provides financial assistance in the form of Grants to support early stage research and development efforts with a specific scope of work with clear objectives;
- Historically, SETO has released Funding Opportunities Announcements (called Incubator or Incubator topic)[5] restricted to for-profit entities and focused on moving innovative ideas from the proof of concept

stage to achieving market adoption. Financial Assistance is in the form of Cooperative Agreements in this case;

- The Technology Commercialization Fund[6] promotes federal research and development investments in technology with commercial potential where National Laboratories are the lead applicants and require a commercial, private-sector partner to commit a 50% project cost share and be involved in project formation and execution.

Please read the relative Funding Opportunity Announcements to learn more about eligibility criteria and cost share requirements of each program. Please note that these programs may or may not be announced in the future, based on congressional appropriation, programmatic decision, and Office priorities.

American-Made Network

Applicant are encouraged to take advantage of the Commercialization Assistance Program. It consists of additional funding on top of the SBIR/STTR funding specifically for commercialization activities. Please read the Funding Opportunity Announcement with more information about this program and how to apply for this extra funding. The American-Made Network[7] is a great resources for finding commercialization providers and vendors with specific expertise in the solar space. The Network helps to accelerate and sustain solar innovation through a diverse and powerful network that includes national laboratories, energy incubators, investors, facilities and other valuable industry partners from across the United States who engage, connect, mentor, and boost the efforts of small businesses. The Network helps competitors solve pressing technology challenges, forge connections, and advance potentially game-changing ideas and innovations. It also leverages highly specialized skills, tools, and expertise to strengthen and scale critical connections to support the progress and success of competitors.

Application guidelines

Within this SBIR/STTR Funding Opportunity Announcement, applications submitted to any one of the subtopics listed below must:

- Propose a tightly structured program which includes technical and business objectives that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are referenced to a benchmark;
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis that clearly identifies assumptions and sources of input data;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Applicants are encouraged to include a summary of the objectives expected to be achieved by the end of the period of performance of Phase I using the table below. Each Application should include technical, business, and stakeholder engagement-related objectives with clear, quantifiable, measurable, verifiable, aggressive yet realistic success metrics and clear definitions of how completion of an objective will be assessed. Completion of a task or activity should not be considered an objective. In the table below, we provide a series of examples of each objective type intended to guide Applicants while preparing their Application. Although not required, Applicants are strongly encouraged to include a table with the same structure in their Application with relevant objectives for their specific proposal.

Return to Table of Contents

THIS TABLE IS PROVIDED AS AN EXAMPLE ONLY. PERFORMANCE METRICS AND SUCCESS VALUES LISTED HERE SHOULD BE CONSIDERED AS EXAMPLES AND DO NOT NECESSARILY REPRESENT OFFICE GOALS OR SUCCESS METRICS FOR THIS TOPIC.						
#	**Month of completion**	**Performance Metric**	**Success Value**	**Assessment Tool / Method of Measuring Success Value**	**Verification Process**	**Metric Justification, Additional Notes**
1	2	Cell efficiency	> 25% efficiency	Average, standard deviation. At least 10 cells measured under standard conditions. Standard deviation < 1% (absolute efficiency)	Raw data and report sent to DOE for verification	The success value was chosen based on initial cost modeling: efficiency lower than 25% makes this material not competitive with current state of the art
2	3	Circuit model curation	> 30 models, of which at least 20 suitable for testing	Count. 30 realistic and anonymized candidate distribution circuit models identified, of which at least 20 are suitable for detailed testing	Report sent to DOE with description of circuit models including load models, impedances, and connectivity characteristics	Load models, impedances, and connectivity characteristics have to be included in the report to assess the feasibility of the proposed circuits
3	4	Webinar	> 100 participants, of which at least 20 installers and at least 40 developers	Count. A minimum of 100 people should attend for at least 50% of the webinar. The audience should include at least 20 installers operating in the states object of this award, and at least 40 developers. The webinar should include effective ways to engage with the audience, including but not	Link to the webinar sent to DOE before the event. Report sent to DOE including slides presented, list of attendees and their affiliation after the conclusion of the event.	Specific audience groups identified to make sure that the relevant stakeholders will receive the content developed during this award.

Return to Table of Contents

THIS TABLE IS PROVIDED AS AN EXAMPLE ONLY. PERFORMANCE METRICS AND SUCCESS VALUES LISTED HERE SHOULD BE CONSIDERED AS EXAMPLES AND DO NOT NECESSARILY REPRESENT OFFICE GOALS OR SUCCESS METRICS FOR THIS TOPIC.						
#	**Month of complet ion**	**Performa nce Metric**	**Success Value**	**Assessment Tool / Method of Measuring Success Value**	**Verification Process**	**Metric Justification, Additional Notes**
				limited to interactive polls and live Q&A sessions		
4	4	Feedback	> 10 potentia l users	Count. A minimum of 10 potential users of the tool will undergo a demo of the software (in-person or webinar) and provide their feedback. Users must provide specific feedback as to the minimum availability and response time they require for their specific use case.	Documentation of feedback, written approval/signatur e from feedback providers, and a justified plan to implement or reject recommendations submitted to DOE. Documentation should also include the proposal for availability and response time metrics with justification from the feedback providers.	User feedback is a critical part of an iterative development cycle to ensure the solution is useful to potential off-takers.
5	4	Module lifetime	> 30 years	Accelerated testing conducted according to testing procedures listed in IEC 1234	Measured at testing facility approved by DOE. Data and report sent to DOE for verification	IEC 1234 is the industry-used module degradation test
6	5	Heliostat installed cost	≤ \$50/m2	Class 3 cost estimate conforming to DOE G 413.3-21 Cost Estimating Guide. Average expected accuracy range +20%/-15%	Cost model sent to DOE, including assumptions used for input parameters, methodology for the sensitivity analysis, supporting documents used	Success metrics defined in the FOA

Return to Table of Contents

THIS TABLE IS PROVIDED AS AN EXAMPLE ONLY. PERFORMANCE METRICS AND SUCCESS VALUES LISTED HERE SHOULD BE CONSIDERED AS EXAMPLES AND DO NOT NECESSARILY REPRESENT OFFICE GOALS OR SUCCESS METRICS FOR THIS TOPIC.						
#	**Month of completion**	**Performance Metric**	**Success Value**	**Assessment Tool / Method of Measuring Success Value**	**Verification Process**	**Metric Justification, Additional Notes**
					to determine the bill of materials.	
7	5	Letters of Support	5 letters	Count. A minimum of 5 letters of support from domestic manufacturers. Includes one module producer with capacity over 200MW annually.	Letters delivered to DOE	Engaging with a large domestic module manufacturers is essential to show there are interested technology off-takers
8	6	Availability and response time of API addressable database	Availability and response time metrics determined and agreed to in #4	Ingest data, including time-series, containing a minimum of 1 year of historical data representing a fleet of 10 GW or solar to an API-addressable database. Conduct at least 50 randomized queries over a period of 7 days and track results.	Live demonstration of subset of queries and supporting documentation including operations report and logs collected during randomized testing.	To be commercially relevant, the database software under development must meet metrics identified by potential users at a scale that is relevant to their use cases.
9	6	Simulation validation	Single feeder simulation	Power flows validated on a single realistic distribution feeder in simulation. Phasor tracking shows agreement with	Quantitative simulation results from basic tools sent to DOE	5% agreement is required to assess the quality of the simulation tools.

Return to Table of Contents

THIS TABLE IS PROVIDED AS AN EXAMPLE ONLY. PERFORMANCE METRICS AND SUCCESS VALUES LISTED HERE SHOULD BE CONSIDERED AS EXAMPLES AND DO NOT NECESSARILY REPRESENT OFFICE GOALS OR SUCCESS METRICS FOR THIS TOPIC.

#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
				expected power flows at every circuit node to better than 5%		
10	7	Figure of merit	> 0.92	Figure of merit for t = 100h and T = 750 C calculated. Student's t-test; 95% C. I.	Data and report sent to DOE	The temperature is appropriate for the FOA goals; 100h is still fairly short but much better than 1h or 10h; the FOM respects the competing interplay of absorptivity and emissivity, it also reflects the importance of concentration factor.
11	8	Independent expert review of security architecture	Third party review	Report by independent third-party cybersecurity expert reviewing the architecture and providing feedback on potential weaknesses.	Security review report sent to DOE	Implications of new platform architecture in the context of new concerns around cybersecurity must be investigated and mitigated if necessary.
12	9	Module efficiency	> 25% efficiency	Average, standard deviation. At least 10 modules measured under standard conditions. Standard deviation < 1% (absolute efficiency)	Measured at testing facility approved by DOE. Data and report sent to DOE for verification	The success value was chosen based on initial cost modeling: efficiency lower than 25% makes this technology not competitive with current state of the art
13	9	Binding letters of intent	2 letters	Count. A minimum of 2 letters of intent from relevant stakeholders committing to	Letters delivered to DOE	Success of the award will be measured by successful technology transfer to private entities.

THIS TABLE IS PROVIDED AS AN EXAMPLE ONLY. PERFORMANCE METRICS AND SUCCESS VALUES LISTED HERE SHOULD BE CONSIDERED AS EXAMPLES AND DO NOT NECESSARILY REPRESENT OFFICE GOALS OR SUCCESS METRICS FOR THIS TOPIC.						
#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
				fabricate and test a large scale prototype of this technology		
14	9	Contract	> 1	Count. At least one agreement with a non-team-member to share data and beta test the solution.	Agreement delivered to DOE	Success of the award will be measured by successful technology transfer to private entities.

In this Topic, SETO seeks applications for the development of innovative and impactful technologies in the areas of:

a. TECHNOLOGY TRANSFER OPPORTUNITY: Microwave Photoconductance Spectrometer for Roll-to-Roll Deposited Semiconductor Materials

Microwave photoconductance measurements are an established industrial and scientific tool for studying photovoltaic materials. The most common technique uses a radio or microwave-frequency electric field to probe the photoconductive response of a semiconductor in response to a short pulse of laser light, quantifying the photoconductance lifetime as the primary metric of material quality. However, commercially available tools are designed around silicon manufacturing technology – characterization and imaging of individual wafers, bricks, or ingots (e.g. the product offerings from Semilab Semiconductor Physics Laboratory Co. Ltd. & Freiberg Instruments GmbH). These are complex, expensive tools that include integrated pulsed laser systems and fast transient digitizers so that the photoconductance lifetime can be resolved.

The advent of new photovoltaic materials that will be manufactured through roll-to-roll printing processes present new challenges and opportunities for metrology. A prime example is the emerging class of hybrid organic lead halide perovskites. These materials are formed from solution-phase crystallization directly on the printed roll, demanding metrology tools that can be used to probe the electronic quality of the material as it forms in real time. Our technology is intended for this purpose, using a highly sensitive microwave circuit and detection scheme to measure the steady-state photoconductance of thin films deposited on an electrode surface. We anticipate that as roll-to-roll fabrication processes begin to dominate the photovoltaic market, our proposed metrology method will naturally displace those existing tools that were developed and designed for the wafer manufacturing paradigm.

At steady-state, the photoconductance of a semiconductor sample is proportional to the product of charge carrier yield, mobility, and lifetime – all crucial characteristics of high-performance solar absorber materials. Moreover, the measurements are fast, non-contact, and amenable to both spatial and spectroscopic mapping of a moving roll. The National Renewable Energy Laboratory's (NREL) desire is to develop our internally-developed lab-scale microwave photoconductance instrument into a prototype of a viable commercial metrology tool, which could include (i) miniaturization of the instrument, (ii) demonstration of spectroscopic and spatial mapping, and/or (iii) implementation on an experimental manufacturing line.

National Renewable Energy Laboratory Information:
Licensing Information: National Renewable Energy Laboratory
Contact: Bill Hadley; bill.hadley@nrel.gov; (303) 275 3015
License type: Non-Exclusive
Patent Status: Pending
Publication date:
Filing date:

Questions – Contact: solar.sbir@ee.doe.gov

b. Affordability, Reliability, and Performance of Solar Technologies

In 2018, solar power generated 2.3% of the annual net generation in the United States (4.6% of the net summer capacity), and solar installation represented 22% of all new U.S. electric generation in 2018[1]. If the price of solar electricity and/or energy storage declines more rapidly than projected, the growth rate can be further accelerated. But solar is more than just a source of affordable electricity; it also provides the potential to improve grid reliability and resilience, increase employment, create business opportunities, increase energy diversity, expand domestic manufacturing, and provide environmental benefits.

In this subtopic, SETO is seeking solutions that can advance solar energy technologies by lowering cost[2] as well as facilitate the secure integration into the nation's energy grid. Applications should fall within one of these areas: advanced solar systems integration technologies, concentrating solar thermal power technologies, or photovoltaic technologies.

SETO is particularly interested in applications developing:

- Technologies which can reduce the manufacturing costs of solar energy system components or sub-components to boost domestic energy manufacturing and increase U.S. manufacturing competiveness;
- Technologies that can measure, validate, or increase outdoor photovoltaics system reliability. Examples include, but are not limited to, instrumentation for field diagnostics of PV modules and/or systems, software to automate analysis fielded modules, and module-level or system-level solutions to increase reliability and decrease operation and maintenance (O&M) costs of PV systems.
- Technologies which enhance the ability of solar energy systems to contribute to grid reliability, resiliency and security;
- Technologies / solutions that reduce the balance of system costs of a photovoltaic system;
- Technologies that build on other SETO programs and/or leverage results and infrastructure developed through these programs. In the last few years, SETO has funded several programs to support multi-stakeholder teams as they research and develop solutions to reduce significant barriers to solar energy adoption through innovative models, technologies, and real-world data sets. The areas of interest, analysis, taxonomies, and best practices developed from these programs can be leveraged as the impetus for small business innovation. Relevant programs include:

- Innovative Pathways[3] - The projects develop and test new ways to integrate emerging technologies into the energy industry and unlock private sector resources to support energy innovation.
- DuraMAT[4] - Durable Module Materials Consortium of national labs and universities with the goal to discover, develop, de-risk, and enable the commercialization of new materials and designs for PV modules.
- PVPMC[5] – The PV Performance Modeling Collaborative group is interested in improving the accuracy and technical rigor of PV performance models and analyses. Such models are used to evaluate current performance (performance index) and determine the future value of PV generation projects (expressed as the predicted energy yield) and, by extension, influence how PV projects and technologies are perceived by the financial community in terms of investment risk.
- Orange Button[6] - Supports the creation, adoption, and utilization of industry-led open data standards for rapid and seamless data exchange across the solar value chain from origination to decommissioning
- Solar Energy Innovation Network[7] - A program that supports multi-stakeholder teams who research and share solutions to reduce barriers to solar energy adoption using real-world data in areas, as defined in the Round 2 solicitation released on July 25, 2019, such as rural solar adoption and solar adoption by commercial and industrial off takers. Tools and products which could help potential participants reach the goals of Round 2 are of interest.
- Any technology developed through academic or national lab research efforts within the SETO funding opportunities. A complete map of current and previous awards is available in the Office website[8].

Applications must include a clear assessment of the state of the art and how the proposed technology would represent a significant improvement, along with a basic cost-model analysis showing a path to becoming cost-competitive with current state of the art and the potential to increase the utilization of solar generation in the grid.

Applications will be considered non responsive and declined without external merit review if within one of these areas:

- Applications for proposed technologies that are not based on sound scientific principles (e.g., violates the laws of thermodynamics);
- Applications that fall in any of the other subtopics listed in this funding opportunity announcement;
- Business plans or proofs-of-concept that do not include documentation supporting the necessity or benefit of the plan or concept. Competitive approaches in this application segment should be clearly defined in the application;
- Undifferentiated products, incremental advances or duplicative products;
- Projects lacking substantial impact from federal funds. This subtopic intends to fund projects where federal funds will provide a clear and measurable impact, (e.g. retiring risk sufficiently for follow-on investment or catalyzing development.) Projects that have sufficient monies and resources to be executed regardless of federal funds are not of interest;
- Applications focusing exclusively on HVAC or water heating applications;
- Technologies related to concentrated PV or solar spectrum splitting;
- Duplicative software solutions with many existing competitors in the market, including software to facilitate system design or system monitoring and any software solution to improve customer

acquisition processes. Hardware technologies that require also software innovation will be considered, as well as integrated hardware/software solutions.

This subtopic seeks to assist independent small businesses which plan to can continue to grow, successfully bring a new technology into the market, and identify a profitable, self-sustaining business opportunity based on their innovation. This subtopic is not intended for creating a product, organization, service, or other entity or item which requires continued government support. This subtopic does not intend to fund work that has already received federal support for similar technology at the same technology readiness level.

Questions – Contact: solar.sbir@ee.doe.gov

References:

1. U.S. Department of Energy, Solar Technologies Office, https://energy.gov/solar-office
2. U.S. Department of Energy, 2017, Energy Department Announces Achievement of Sunshot Goal, New Focus for Solar Energy Office, https://www.energy.gov/articles/energy-department-announces-achievement-sunshot-goal-new-focus-solar-energy-office
3. U.S. Department of Energy, Goals of the Solar Energy Technologies Office, U.S. Department of Energy Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/eere/solar/goals-solar-energy-technologies-office
4. American-Made Solar Prize: Accelerate and Sustain American Solar Innovation, https://americanmadechallenges.org/solarprize/index.html
5. U.S. Department of Energy, Technology to Market Competitive Awards, Solar Energy Technologies Office, https://www.energy.gov/eere/solar/technology-market-competitive-awards
6. U.S. Department of Energy, Funding Opportunities, Solar Energy Technologies Office, https://www.energy.gov/eere/solar/funding-opportunities
7. American-Made Network Partners, https://americanmadechallenges.org/network.html

References: Subtopic b:

1. Feldman, D., Margolis, R., 2019, Q4 2018/2019 Solar Industry Update, National Renewable Energy Laboratory (NREL), https://www.nrel.gov/docs/fy19osti/73992.pdf
2. Cole, W., Frew, B., Gagnon, P., et al, SunShot 2030 for Photovoltaics (PV): Envisioning a Low-cost PV Future, National Renewable Energy Laboratory (NREL), https://www.nrel.gov/docs/fy17osti/68105.pdf
3. U.S. Department of Energy, Innovative Pathways – EERE Technology-to-Market Initiative, Solar Technologies Office, https://www.energy.gov/eere/solar/innovative-pathways-eere-technology-market-initiative
4. New Materials and Designs for Photovoltaic Modules Providing Low-cost Energy, DuraMat, https://www.duramat.org
5. PVPerformance Modeling Collaborative, https://pvpmc.sandia.gov

6. U.S. Department of Energy, Orange Button – Solar Blankability Data to Advance Trasactions and Access (SB-DATA), Solar Energy Technologies Office, https://www.energy.gov/eere/solar/orange-button-solar-bankability-data-advance-transactions-and-access-sb-data

7. U.S. Department of Energy, Solar Energy Innovation Network, Solar Energy Technologies Office, https://www.energy.gov/eere/solar/solar-energy-innovation-network

8. U.S. Department of Energy, Solar Projects Map, Solar Energy Technologies Office, https://www.energy.gov/eere/solar/solar-projects-map

12. VEHICLES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Last year, vehicles transported 11 billion tons of freight, more than $32 billion worth of goods each day, and moved people more than 3 trillion vehicle-miles. The U.S. Department of Energy's Vehicle Technologies Office (VTO) provides low cost, secure, and clean energy technologies to move people and goods across America. VTO (https://www.energy.gov/eere/vehicles/vehicle-technologies-office) [1] focuses on reducing the cost and improving the performance of vehicle technologies including advanced batteries, electric traction drive systems, lightweight materials, advanced combustion engines, and advanced fuels and lubricants. VTO supports the development and deployment of advanced vehicle technologies, including advances in electric vehicles, engine efficiency, and lightweight materials. Since 2008, the Department of Energy has helped reduced the costs of producing electric vehicle batteries by more than 75%. DOE has also pioneered improved combustion engines that have saved billions of gallons of petroleum fuel, while making diesel vehicles as clean as gasoline-fueled vehicles.

Applications may be submitted to any one of the subtopics listed below but all applications must:

- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a baseline (i.e. Multi-Year Program Plan (MYPP) or Roadmap targets and/or state of the art products or practices);
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis;
- Justify all performance claims with theoretical predictions and/or relevant experimental data;
- Applications that duplicate research already in progress will not be funded, all submissions therefore should clearly explain how the proposed work differs from other work in the field.

Grant applications are sought in the following subtopics:

a. Electric Drive Vehicle Batteries

Applications are sought to develop electrochemical energy storage technologies that support commercialization of micro, mild, and full HEVs, PHEVs, and EVs. Some specific improvements of interest include the following: new low-cost materials; alternatives or recycling technologies of energy storage critical materials defined at: https://www.energy.gov/sites/prod/files/2019/07/f64/112306-battery-recycling-brochure-June-2019%202-web150.pdf [1]; high voltage and high temperature non-carbonate electrolytes; improvements in manufacturing processes – specifically the production of mixed metal oxide cathode materials through the elimination or optimization of the calcination step to reduce cost and improve throughput, speed, or yield; novel SEI stabilization techniques for silicon anodes; improved cell/pack design minimizing inactive material; significant improvement in specific energy (Wh/kg) or energy density (Wh/L); and improved safety. Applications must clearly demonstrate how they advance the current state of the art and meet the relevant performance metrics listed at www.uscar.org/guest/article_view.php?articles_id=85 [2].

When appropriate, the technology should be evaluated in accordance with applicable test procedures or recommended practices as published by the Department of Energy (DOE) and the US Advanced Battery Consortium (USABC). These test procedures can be found at www.uscar.org/guest/article_view.php?articles_id=86 [3]. Phase I feasibility studies must be evaluated in full cells (not half-cells) greater than 200mAh in size while Phase II technologies should be demonstrated in full cells greater than 2Ah. Applications will be deemed non-responsive if the proposed technology is high cost; requires substantial infrastructure investments or industry standardization to be commercially viable; and/or cannot accept high power recharge pulses from regenerative breaking or has other characteristics that prohibit market penetration. Applications deemed to be duplicative of research that is already in progress or similar to applications already reviewed this year will not be funded; therefore, all submissions should clearly explain how the proposed work differs from other work in the field.

Questions – Contact: Samm Gillard, Samuel.Gillard@ee.doe.gov

b. Gallium Nitride Device Qualification for Electric Drive Vehicle Power Electronics

High voltage onboard power electronics, including converters and inverters, are essential for electric drive vehicle operation, and the Vehicle Technologies Office (VTO) has established cost and performance targets that need to be met to enable greater electric vehicle adoption. Specifically, power electronics R&D targets and research pathways have been outlined by the U.S. DRIVE partnership Electrical and Electronics Technical Team in their roadmap [1].

The EETT Roadmap specifically address the performance benefits of WBG semiconductors, but their current high cost is a barrier to high volume automotive adoption. With production on larger area (> 100 mm, or 4”) substrates, GaN devices are on a pathway to compete alongside silicon (Si) power devices, where the cost of fabrication is the primary driver for device cost, and a high yield will allow for a low overall cost of devices.

Vehicle power electronics can take advantage of these GaN devices that offer significantly smaller on-state resistance as compared to current Si switches and enable very high power density power electronics for use in electric drive vehicles. The high switching frequency capabilities of GaN switches also allows for increased efficiencies and reduced passive device requirements for power inverter applications. While lower current (<20A) GaN devices offered by few suppliers have already been introduced for some applications, few devices are fully qualified for automotive applications at higher current levels of > 20 Amps and > 600 Volts.

This topic seeks to address this barrier through demonstrating the successful production of > 20A, > 600V rated GaN devices on ≥ 100mm substrates that are designed for automotive qualification, and suitable for use in electric drive vehicle onboard power electronics. Specifically, devices produced should show automotive application readiness through passing full or partial qualification specifications or standards at high device production yields. Device production quantities are not expected to be sufficient to pass full qualification for Phase 1 projects. Where possible, applicants should show a relationship to, and demonstrate an understanding of, automotive application requirements and environments. Examples include surface and/or substrate treatments and processing, and compatibility with existing power module packaging and processing.

Proposals should also describe the cost of manufacturing GaN switches compared to competing Si switches, including details such as costs and availability of commercial GaN substrates, epi-layers, and additional equipment needed. These costs should be linked to a commercially viable business model for large scale manufacturing that could be executed upon in Phase II and should approach price parity with Si switches on a cost per amp basis.

Questions – Contact: Steven Boyd, steven.boyd@ee.doe.gov

c. Research on Energy Efficiency in Emerging Mobility Systems

The introduction of disruptive transportation technologies and services, such as connected and automated vehicles, car-sharing, and ride-hailing services, provides new, low-cost mobility options for consumers. Additionally, the evolving retail sector, shaped by the convenience of online shopping, has resulted in not only a shift in how we transport and deliver goods, but it has also had ripple effects in personal transportation. This transforming mobility landscape presents a significant opportunity to improve economic and energy productivity and advance safety, affordability, and accessibility in the transportation sector. While these changes in the transportation system can provide benefits to the American public, they also present risks, challenges, and questions that must be addressed. DOE conducts research to understand how this transformation will affect transportation energy consumption and identifies opportunities to create more efficient, affordable, reliable, accessible, and secure transportation options that enhance mobility for individuals and businesses. Within DOE's Office of Energy Efficiency and Renewable Energy (EERE), the EEMS Program is responsible for this research portfolio.

The EEMS Program supports VTO's mission to improve transportation energy efficiency through low-cost, secure, and clean energy technologies. EEMS conducts early-stage research and development (R&D) at the vehicle, traveler, and system levels, creating knowledge, insights, tools, and technology solutions that increase mobility energy productivity for individuals and businesses. This multi-level approach is critical to understanding the opportunities that exist for optimizing the overall transportation system. The EEMS Program uses this approach to develop tools and capabilities to evaluate the energy impacts of new mobility solutions, and to create new technologies that provide economic benefits to all Americans through enhanced mobility.

Applications are sought to develop novel solutions and technologies that enable energy efficiency improvements in personal and freight mobility by addressing key knowledge gaps related to connectivity, automation, and artificial intelligence applications for on-road transportation. Potential solutions should support a pathway to transportation system-wide energy reduction, while maintaining or improving access to mobility, and may include, but are not limited to, the following:

- Hardware technologies such as:
    - Advanced devices, sensors, and components that use connectivity and automation to significantly reduce vehicle- and transportation system-level fuel consumption without negatively impacting mobility.

  - Personal mobility concepts that incorporate novel materials and/or powertrain designs, compatible with a future automated, connected, and shared transportation scenario, that result in transportation energy savings and mobility system improvements.
- Non-hardware solutions such as:
  - Software and control algorithms that use real-time data to optimize vehicle or traffic behavior to achieve energy reductions and mobility enhancements.
  - Computational methods that incorporate artificial intelligence or machine learning to identify and leverage energy reduction opportunities in the transportation network while improving mobility access.

Applications must quantify the baseline performance of the proposed system to be researched or further developed through this solicitation, describe the proposed research, and quantify and describe the expected energy savings and mobility impacts that directly result from the proposed technology. Applications deemed to be duplicative of research that is already in progress by VTO, as well as by other agencies, including state and local governments, and by the private sector, will not be funded; therefore, all submissions should clearly explain how the proposed work differs from other work in the field.

Questions – Contact: Prasad Gupte, Prasad.Gupte@ee.doe.gov

d. Multifunctional Composite Materials and Structures for Vehicle Applications

Novel multifunctional composite materials and structures have the capability to reduce weight and volume as well as costs of "conventional" structural components by performing engineering functions beyond load carrying. The multifunctionality that couples between structural performance and additional functionalities (e.g., electrical, magnetic, optical, thermal, chemical, biological, etc.) is critical to the growth of artificial intelligence in the automotive industry. Multifunctional structures can sense, diagnose, and respond for adjustment with minimum external intervention; allow alternation of shape functionality and mechanical properties on demand; and structural integration of power harvest/storage/transmission capabilities for "self-sustaining" systems [1]. Such multifunctional composite materials and structures are required to make a step change in vehicle energy efficiency, particularly for electric and autonomous vehicles [2].

This subtopic seeks proposals to develop, design, and test the feasibility of the proposed innovations that can incorporate the autonomic structures, adaptive structures, and self-sustaining systems in the next generation of high-performance and high-efficient vehicles.

Questions – Contact: Felix Wu, felix.wu@ee.doe.gov

References:

1. Vehicle Technologies Office (VTO), U. S. Department of Energy, https://www.energy.gov/eere/vehicles/vehicle-technologies-office

References: Subtopic a:

1. The Department of Energy's Critical Materials Strategy, U. S. Department of Energy, https://www.energy.gov/sites/prod/files/2019/07/f64/112306-battery-recycling-brochure-June-2019%202-web150.pdf

2. Energy Storage System Goals, United States Council for Automotive Research, LLC, http://www.uscar.org/guest/article_view.php?articles_id=85

3. USABC Manuals, United States Council for Automotive Research, LLC, www.uscar.org/guest/article_view.php?articles_id=86

References: Subtopic b:

1. Electrical and Electronics Technical Team Roadmap, 2017, U.S. DRIVE Partnership, https://www.energy.gov/sites/prod/files/2017/11/f39/EETT%20Roadmap%2010-27-17.pdf

References: Subtopic c:

1. Stephens, T. S., Gonder, J., Chen, Y., et al, 2016, Estimated Bounds and Important Factors for Fuel Use and Consumer Costs of Connected and Automated Vehicles, National Renewable Energy Laboratory, p. 48. https://www.nrel.gov/docs/fy17osti/67216.pdf

2. Office of Energy Efficiency and Renewable Energy, 2017, The Transforming Mobility Ecosystem: Enabling an Energy Efficient Future, U.S. Department of Energy, p. 30, https://energy.gov/eere/vehicles/downloads/transforming-mobility-ecosystem-report

3. Energy Efficient Mobility Systems FY2018 Annual Progress Report https://www.energy.gov/sites/prod/files/2019/04/f62/VTO_2018_APR_EEMS_%20032919_compliant_0.pdf

References: Subtopic d:

1. Gardiner, G., 2015, Multifunctional Composites: Past, Present, and Future, Composites World, https://www.compositesworld.com/blog/post/multifunctional-composites-past-present-and-future

2. Asp, L.E., Greenhalgh, E.S., 2012, Multifunctional Composite Materials for Energy Storage in Structural Load Paths, ARPA-E Safe Energy Storage Systems for Electric Vehicles, https://arpa-e.energy.gov/sites/default/files/documents/files/CSESS%20Asp.pdf

13.WATER

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Office of Energy Efficiency and Renewable Energy's Water Power Technologies Office (WPTO) (http://energy.gov/eere/water/water-power-program) conducts early-stage research and development to strengthen the body of scientific and engineering knowledge enabling industry to develop new technologies that increase US hydropower and marine and hydrokinetic (MHK) generation. Hydropower and MHK technologies generate renewable electricity that supports domestic economic prosperity and energy security while enhancing the reliability and resiliency of the US power grid. WPTO is seeking applications for both Hydropower and MHK technologies.

All applications must:

- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a baseline;

- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis; and
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopics:

a. Research & Development for Testing of Oil-Free Bearings/Bushings for Hydropower Components

Hydropower technologies typically convert the potential energy of water moving from a higher elevation to a lower elevation into mechanical energy through a turbine, spinning it, which in turn activates a generator to produce electricity. The most common type of hydroelectric power plant in the United States is an impoundment facility. An impoundment facility, typically a large hydropower system, uses a dam to store river water in a reservoir. The water releases are controlled to meet the varying electricity and/or other demands. Various types of equipment is used to efficiently control those releases such as gates, valves, turbine wicket gates etc. There are two main types of hydropower turbines: impulse and reaction. The turbines are carefully selected/designed to make full use of the water releases and potential head. The type/configuration of turbine depends on many parameters; the most important parameters are head and flow and their variations. Reaction turbines are further classified as fixed blade and adjustable blade propeller turbines generally known as Kaplan turbines; which are good for low head high flow applications. The blade adjustability makes Kaplan turbines more efficient over a wide range of head and flows. Lubrication in the form of petroleum based oils and greases has been typically used in the moving parts for these turbines and other hydropower equipment. However, these lubricants have low biodegradability and can be toxic. In a 2014 settlement with Columbia Riverkeeper the U.S. Army Corps of Engineers (USACE) agreed to install "best available technology" to control spills among other things. (https://www.columbiariverkeeper.org/sites/default/files/2014/08/PR-Columbia-Riverkeeper-v-Corps-dams-settlement.pdf).

In FY-2018 EERE/WPTO released a topic on "Development of Environmentally-Acceptable Lubricants for Hydropower Applications" to mitigate the threat to aquatic ecosystems if unexpected leakages or spills of petroleum based oils occur. In addition to assessing the use of Environmentally Acceptable Lubricants, USACE is working on the use of oil-free (self-lubricating) bearings/bushings for various components including Kaplan turbine runners. As part of this work USACE has identified the need for standardized testing of such bearings/bushings specifically for Kaplan turbine trunnions in water filled runner hubs. This will help to increase the confidence in bearing performance for long durations under appropriate loading conditions (e.g., load, temperature, revolutions per minute, duration, fatigue, corrosion, and desired bearing life) and may be used to inform development of appropriate design, testing standards and guide specifications.

The oil-free bearing technology is presently being used by turbine manufacturers and being produced by various bearing/bushing companies. However the bearing/bushing companies use their own propriety materials, methods, and design criteria/test standards. This leads to uncertainty on how to establish the durability of the bearings/bushings and to make a suitable comparison based on common testing. This topic is expected to help research the various types of self-lubricating bearings/bushing in use by the hydropower industry and develop appropriate standard tests to help make those comparisons and evaluate the commercial potential of performing those tests for interested parties. A similar effort was undertaken previously to study the application of self-lubricating bearings/bushings for the wicket gate application (https://erdc-library.erdc.dren.mil/xmlui/bitstream/handle/11681/19880/CERL-TR-99-104.pdf?sequence=1).

The applicants are encouraged to work with various end users such as the Bureau of Reclamation, USACE, various Public Utilities, other public and private hydropower plant owners, turbine manufacturers, bearings/bushings manufacturers, and other hydropower component manufacturers who use heavy duty self-lubricating bearings.

In Phase I the applicants will:

- Research the various types of oil-free bearings presently being used for various hydropower components with emphasis on Kaplan turbine runners and prepare a catalog of available bearings/bushings used especially for heavy duty applications;
- Research and establish the loading conditions and design requirements for the bearings/bushings for the purpose for which the bearings is to be used;
- Research the commercial potential for testing of such bearings/bushings and their materials in a laboratory environment;
- Develop suitable suggested guide specifications for testing of the bearings/bushings to achieve the purpose for which the bearing/bushing is to be used;
- Research and develop testing requirements for such bearings/bushings specific to the end user
- Research the requirement of specific testing equipment and develop specifications for any specialized equipment required for testing of the bearings/bushings; and
- Prepare a preliminary design of the testing equipment needed.

The Hydroelectric Design Center (HDC) of USACE is presently researching on establishing the longevity of self-lubricating bearings/bushings used in Kaplan turbines. Collaboration with HDC to achieve the project goals is highly encouraged.

In Phase II of the project the applicant will finalize the design of the testing equipment, setup the testing apparatus identified in Phase I, perform tests on a minimum of 10 commercially available self-lubricating bearings, complete the research on the commercial potential of laboratory testing requirements, and develop a report with recommendations on testing needs and the work accomplished under the grant. This report should also detail the commercial potential and a path forward to commercialize the laboratory testing of bearings/bushings including materials testing.

Questions – Contact: Rajesh Dham, rajesh.dham@ee.doe.gov

b. Innovative Sensing and Data Platforms for Water and Hydropower

Sensing innovation focuses on creating improved data accuracy, availability, and overall value. Our ability to understand, account, and predict water conditions will be greatly improved by tools that can cost-effectively create precise or real-time datasets over large physical areas, or continuously process very large datasets such as satellite imagery. These tools can advance our ability to understand hydropower potential and simultaneously advance other water uses such as assess streamflows and watershed/land-use conditions that drive streamflows.

Success in sensor innovation exists across a wide spectrum from purely physical sensors to advanced capabilities in data analysis. This sub-topic is designed to solicit proposals across this range and enhance the performance and value of hydropower systems. Successful applications must be applicable to hydropower or riverine systems including but not limited to: water characteristics (flow, quality, availability, loss), mechanical systems (vibration, strain, condition), operation (performance management, maintenance, cascading plant coordination) and safety (impoundment integrity, security, public safety). Proposals may address one or multiple areas along this spectrum; however, proposals will not be evaluated based on the breadth of topics they cover, but on the likelihood of achieving meaningful impact in at least one area.

Regarding physical sensor capabilities, the unprecedented growth of satellite observation capabilities and other novel sensor applications represent a significant opportunity to change hydropower systems paradigm via more accurate information, higher resolution data, faster access/real time sensing, and data over a wider range of systems. These advanced capabilities have the potential to improve information availability, accuracy and resolution over the spectrum of hydropower and river systems including ecological, operational, safety, and hydrological. These sensing solutions have the potential to improve our understanding of earth observation parameters such as river discharge, reservoir surface levels, soil moisture, precipitation, water quality and be further developed to provide a dynamic and real-time understanding of these observations. Similarly, advanced sensors have the potential to better represent the complex and large scales of hydropower performance and health. Parameters associated with the broad spectrum of riverine, terrestrial and remote sensors include impoundment integrity, hydropower component level wear, and power system dynamics. The tools and techniques of these sensing platforms present the hydropower community with a unique opportunity to develop new insights to advance fundamental science and robust decision-support platforms. Examples of innovative solutions in this space include, but are not limited to: miniature systems to larger scale technologies, such as CubeSat deployments, unmanned aerial vehicles, observation balloons, or opportunistic sensing approaches, in addition to more conventional sensor capabilities such as stick on sensors and other novel localized sensors.

In regards to data analysis, the hydropower industry exists in a unique data paradigm wherein many cases a rich body of data exists for an individual attribute or component but in many other instances data is of limited availability, quality, potential for data sharing, or consolidation. Likewise, stream-flow and water quality data is fragmented and incomplete, and housed in a wide range of often incompatible systems. The need for more effective, and cost-effective analysis of large datasets across both hydropower systems and the water they rely on is anticipated to increase as more of the industry continues to digitalize and this information becomes more broadly available, however an increasingly prevalent challenge is to develop effective mechanisms to leverage this information to drive improved decisions and enhance system value. Existing analytical methods and modeling platforms suffer from the challenge of attempting to be broadly applicable to the diverse set hydropower systems while being able to provide site specific results with a high degree of accuracy and certainty. Artificial intelligence, machine learning, signal processing, among other approaches are currently some of the most promising areas to process, consolidate, and derive value from the wide range of data sources. Some theoretical applications could be water quality monitoring, ecosystem assessment, as well as hydrological parameters such as flow velocity, flood propagation, precipitation, and cloud tracking to inform river basin managements, reservoir operations, or other critical hydrosystems. The WPTO seeks application with practical and/or novel approaches to data with demonstrable value to hydropower systems. Examples in this space can include expedited processing of complex coupled systems, means of collecting novel results from existing data, coupling discrete datasets in innovative means, providing advanced mechanisms of data quality assurance/control.

Application Guidance:
Innovation in sensing platforms for hydropower exists across a wide spectrum of solutions ranging from exclusively sensor based to exclusively data based, and can also exist in a middle ground between the two. In response to this, and to encourage successful applications over this spectrum the Phases descriptions

below are discretized into two parts: (1) Sensor Solutions and (2) Analytics and Data Science. Applicants should identify if their solution is responsive Part 1 or Part 2 exclusively or is responsive to both. Successful applications will responded to the attributes highlighted in the appropriate parts.

The applicants are strongly encouraged to work with agencies currently working in this space such as NASA, NOAA, and USGS to more effectively leverage data and observation systems. In addition applicants are encouraged to engage with various end users including but not limited to the Bureau of Reclamation, USACE, various Public Utilities, other public and private hydropower plant owners, turbine manufacturers, sensor developers, and remote sensing stakeholders to ensure the industry and uptake of the proposed solution.

Advanced Sensor Solutions:

In Phase I applicants to Advanced Sensors will:

- Clearly define the landscape of the system including but not limited to: the solution applicability to the broad hydropower/riverine system, pervasiveness of applicability, alternate solution that currently exist, and articulate the value proposition beyond the state of the art;
- Establish firm characteristics of the data collected along with the means of storing and/or transmitting this data;
- Document concerns and limitations of the application of the solution to the target demographics including security, power supply, and communications;
- Research the commercial potential for development of said solution;
- Outline the lifespan and temporal resolution of the solution;
- Establish applicable standards committees or other relevant bodies to ensure industry uptake;
- Prepare a preliminary design of the testing equipment needed; and
- Indicate the training requirements necessary for use of the solution by an outside user.

In Phase II applicants to Advanced Sensors will:

- Finalize the design of the sensor solution along with any necessary system support;
- Develop the sensor solution as outlined in Phase I;
- Perform a series of testing on the sensor solution over a range of operational conditions;
- Complete the research on the commercial potential the solution;
- Develop a report with recommendations on data collection needs of the industry and how/the extent to which the solution developed mitigates these. This report should also detail the commercial potential and a path forward to commercialize the solution and identify a process for industry uptake.

Analytics and Data Science

In Phase I applicants to advanced analytics will:

- Clearly define the landscape of the system including but not limited to: the solution applicability to the broad hydropower/riverine system, pervasiveness of applicability, alternate solution that currently exist, and articulate the value proposition beyond the state of the art;
- Articulate the data characteristics that will be leveraged in the development of this solution as well as the pervasiveness within the broader hydrosystem landscape;
- Research the commercial potential for testing of such solutions in a practical use case or applicable testing environment;
- Highlight the process necessary to leverage the solution for similar datasets from different locations with potentially different data structures;

- Highlight processes involving high-performance computing such as data storage, data access, parallelization, or other features;
- Document the computational obligations required to develop, run and, if applicable, post-process the solution derived;
- Indicate the personnel training requirements necessary for use of the solution by an outside user; and
- Clearly define the accuracy, uncertainty, and adaptability of the solutions to datasets outside of the bounds of the initial data leveraged to develop the solution.

In Phase II applicants to Advanced Sensors will:

- In Phase II of the project the applicant will finalize the design of the numerical solution;
- Develop the solution along with any necessary coding, user information or guides;
- Perform a wide range of validation tests on the solution to ensure solution consistency, accuracy and uncertainty both under data parameters similar to those used in development of the solution as well as those outside of these bounds (which may include as appropriate temporal-spatial resolution, data quality, data range and data source);
- Clearly demonstrate solution performance using when applied to another location;
- Develop a report with recommendations on data processing needs of the industry and how/the extent to which the solution developed mitigates these. This report should also detail the commercial potential and a path forward to commercialize the solution and identify a process for industry uptake.

Questions – Contact: Rajesh Dham, rajesh.dham@ee.doe.gov

c. Co-Development of Marine Energy Technology at Smaller Scales

The WPTO seeks applications under this subtopic "Co-Development of Marine Energy Technologies at Smaller Scales" (CMETSS) to provide funding for developers of new marine energy prototypes to design systems specific to the needs of an identified end-user in the blue economy. CMETSS seeks to support applicants that use marine and hydrokinetic energy to co-develop solutions specific to energy constraints, as identified by an end-user. Rather than incentivizing the design of a system absent end-user requirements, this subtopic specifically seeks applicants that demonstrate an understanding of the needs of the users of the systems in a specific market application. The intent is to provide near-term marine energy opportunities tightly coupled to end user needs, increasing the odds that technologies will find early market niches and establish pathways towards commercialization.

Activities in the blue economy[2] are frequently grouped into sectors such as offshore aquaculture, maritime defense, offshore energy, ocean observing, and shipping. A common underlying input for many of the activities in the blue economy is energy: fuel for ships, batteries for underwater vehicles, or high-pressure seawater for desalination systems. While some activities have access to cheap and reliable sources of energy, others do not. Energy inaccessibility limits operations and adds unnecessary costs. Removing or reducing these energy constraints through energy innovation could open up new pathways for sustainable economic development.

[2] The World Bank Defines the Blue Economy as "the sustainable use of ocean resources for economic growth, improved livelihoods and jobs, and ocean ecosystem health".

In FY 2019, WPTO released the report *Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets.* The report described eight non-grid applications where marine energy could provide consistent, reliable power. This report served as the foundation for the recently launched Powering the Blue Economy Initiative that supports R&D for non-grid applications of marine and hydrokinetic energy. Blue economy markets present new opportunities and unfamiliar applications of marine and hydrokinetic energy technology developers. So upfront engagement with end-users and coastal communities is essential to successful technology integration to achieve design goals.

CMETSS targets technologies that produce less than 50kW of power, although applicants are not limited to electricity generation, and can include marine energy for propulsion or pumping. The CMETSS topic is market agnostic but requires SBIR Phase I applicants to make a case for their proposed non-grid application through an initial analysis of the market's value and broader impact in their proposal. Should the project be awarded, a more refined market analysis will be required as a deliverable during the period of performance.

Applicants must identify and demonstrate an end-use partner and describe a co-development process for concept design and technology prototyping. Applicants are encouraged to include an end-use partner as a funded project participant, enabling a true co-development process. Applicants must demonstrate that a prototype, with an identified partner, can be designed and built with funds provided in Phase II.

For the purpose of this Phase I award, systems should be designed for a specific market application and demonstrate understanding of the specific requirements for deployment and maintenance. An assessment of the proposed marine and hydrokinetic resource necessary for energy harvesting for the technology should be provided in the Phase I application and refined during the period of performance. While the system should be designed for a particular end-user for the purpose of this grant, the solution should demonstrate potential for scaling and Phase I awardees must perform customer discovery and analysis to understand the potential for commercialization and scaling-up of the solution.

Phase I proof-of-concept work may include fabrication or testing in a laboratory or natural environment as well as computer modeling and simulation. In Phase I, awardee(s) must validate the energy needs of the identified end-user, and present sufficient information demonstrating customer discovery. In Phase II, the awardee(s) will use the designs developed during Phase I to build a functioning prototype to be deployed with an identified potential partner. Phase II awardee(s) must also present a detailed plan for the commercialization of the proposed technology.

In addition to the above requirements (market/value analysis, end user partner identification, statement of target scale) for Phase I, competitive applicants should demonstrate knowledge, experience, and/or capabilities in developing marine technologies and include the following in their application:

- A preliminary design of the proposed system with estimated physical dimensions and a clear description on how the system would operate;
- A drawing or schematic of the proposed system;
- A description of the intended deployment environment or location including identification of key environmental, social, and regulatory challenges;
- The state-of-the-art for incumbent technologies and how the proposed design is an improvement in performance or reduction in cost;
- Details of work to be performed in Phase I including resources required and intended performance targets; and

- Initial description of Phase II work including the scale of the demonstration prototype, the intended test location or facility, and potential end-user partners;

Questions – Contact: Rajesh Dham, rajesh.dham@ee.doe.gov

d. Waterway Debris Remediation Powered by Marine Energy

Each year an estimated eight million tons of plastic waste enters the ocean. It is estimated that there will be one ton of plastic in the sea for every three tons of fish by 2020; by 2050 it will be one for one.

Once plastic becomes water-bound it breaks down into ever smaller pieces over time due to ultraviolet light degradation and the abrasive action of wind and waves, reducing to sizes under 1 millimeter. These plastics are ingested by marine organisms, including fisheries - toxifying one of society's most important forms of sustenance.

Solutions are needed both to stem the flow of plastic debris and to collect plastic debris already in the ocean. With ninety percent of marine debris believed to come from just ten rivers, inland waterways such as rivers and canals are a key to remediation efforts. It is in waterways such as rivers and canals or near the coast in ports and harbor that collection efforts will be most impactful since the debris is still near-intact and concentrated.

Given that most trash finds its way into our oceans through flowing rivers, streams, and other waterways marine and hydrokinetic energy is uniquely positioned to support promising marine debris remediation technologies.

WPTO seeks to fund research and development on systems that integrate one or more forms of marine and hydrokinetic energy into plastic debris remediation systems that perform one or several of the following actions on river and marine debris: collect, aggregate, extract, or monitor and assess.

Phase I work scopes should include proof-of-concept laboratory research of a novel system that utilizes marine and hydrokinetic energy resources to directly or indirectly power a marine or river debris remediation device that leads to detailed technical designs of the proposed system. Proposed systems may be of various physical scales and capacities and should be designed for inland or near-coastal applications. Applicants must choose a suitable location that has marine and hydrokinetic (MHK) energy potential for demonstration of the system. Include a preliminary assessment of the MHK potential in the application. While the system should be designed for a particular location for the purpose of this grant, the solution should demonstrate potential for scaling.

Deep sea applications will not be considered.

During Phase I the applicants will:

- Design systems for a particular location and demonstrate understanding of the specific requirements for deployment and installation at that site.
- Refine the preliminary resource assessment of the marine and hydrokinetic energy potential at the chosen site.
- Perform a customer discovery and analysis to understand the potential for commercialization and scaling-up of the solution to multiple locations globally.

Phase I proof-of-concept work may include component or sub-system testing in a laboratory or natural environment as well as computer modeling and simulation.

Phase II work will include but not limited to the following:

- Based on the designs developed during Phase I a functioning prototype will be built for deployment at the specified location.
- A detailed plan for commercialization of the proposed technology.

In addition to the above requirements for Phase I, competitive applicants should demonstrate knowledge, experience, and/or capabilities in developing marine technologies and include the following in their application:

- A preliminary design of the proposed system with estimated physical dimensions and a clear description on how the system would operate
- A drawing or schematic of the proposed system
- An estimate for the amount of debris (pounds, tons, cubic meters, etc. per unit of time) that could be collected by the debris remediation device along with supporting calculations that notes assumptions;
- A preliminary resource assessment of the intended environment to include both the marine and hydrokinetic energy potential (for example daily or monthly river flow speeds in meters/sec) as well as the amount of debris that flows by the specified location, if available;
- The state-of-the-art for incumbent technologies and how the proposed design is an improvement in performance or reduction in cost;
- Details of work to be performed in Phase I including resources required and intended performance targets; and
- Initial description of Phase II work including the scale of the demonstration prototype, the intended test location or facility, and if possible, end-user partners.

Questions – Contact: Rajesh Dham, rajesh.dham@ee.doe.gov

References:

1. World Economic Forum, 2016, The New Plastics Economy — Rethinking the Future of Plastics, Ellen MacArthur Foundation and McKinsey & Company, http://www.ellenmacarthurfoundation.org/publications

2. Jambeck, J.R., Geyer, R., Wilcox, C., et al, 2015, Plastic Waste Inputs from Land into the Ocean, Science, 347.6223, 768 LP-771, https://science.sciencemag.org/content/347/6223/768

3. Schmidt, C., Krauth, T., Wagner, S., 2017, Export of Plastic Debris by Rivers into the Sea, Environmental Science & Technology, Vol. 51, No. 21, https://pubs.acs.org/doi/abs/10.1021/acs.est.7b02368

4. Waterfront Partnership of Baltimore, Trash Wheel Project, https://baltimorewaterfront.com/healthy-harbor/trashwheels/

5. Thaler, A., 2015, Baltimore's Garbage Wheel, Hakai Magazine, https://www.hakaimagazine.com/news/baltimores-garbage-wheel/

Return to Table of Contents

14. WIND

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy's Wind Energy Technologies Office (WETO) (https://energy.gov/eere/wind) drives innovation through research, development, and testing of advanced wind energy technologies. The portfolio focuses on land-based, offshore, and distributed wind, as well as integration with the grid. The primary goal is cost reduction, while also informing market choices; ensuring the reliability, resilience, and security of wind power and the grid; exploring means for mitigating siting and environmental challenges; and nurturing a robust U.S. manufacturing sector and related workforce. WETO seeks applications for innovations that significantly reduce the cost of energy from U.S. wind power resources from turbines in land-based, offshore, and distributed applications. WETO is seeking proposals for technology innovations with the potential to enable wind power to generate electricity in all 50 states cost competitively with other sources of generation.

In 2018, wind power additions continued at a robust pace, with 7,588 MW of new capacity added in the United States and $11 billion invested. At the end of 2018, over 83,000 wind turbines, totaling 1,127 megawatts (MW) in cumulative capacity, were deployed in distributed applications across all 50 states, the District of Columbia, Puerto Rico, Guam, and the U.S. Virgin Islands. Finally, industry forecasts suggest U.S. offshore wind capacity could grow to 11–16 GW by 2030. With wind power generation exceeding 10% of electricity in 14 states and more than 30% in three of those states, wind is a demonstrated clean, affordable electricity resource for the nation.

WETO aims to advance scientific knowledge and technological innovation to enable clean, low-cost wind energy options nationwide. WETO Research, Development, Demonstration, and Deployment (RDD&D) activities are applicable to utility-scale land-based and offshore wind markets, as well as distributed applications where the turbine is interconnected on the distribution grid at or near the point of end-use. Achieving cost reduction goals will support deployment of wind at high penetration levels, sufficient to meet up to 20% of projected U.S. electricity demand in 2030, and up to 35% in 2050, compared to about 7% of demand in 2018. DOE plays a unique and valuable role in enabling the wind industry and its stakeholders to meet core challenges to industry growth through innovation to reduce wind technology costs and mitigate market barriers, enabling deployment and driving U.S. economic growth.

All applications must:

- Propose a tightly structured program including technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a baseline (i.e. DOE *Wind Vision* [6] or Roadmap targets and/or state-of-the-art products or practices);
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis and justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopics:

Return to Table of Contents

a. Integrated Low-Cost Instrumentation for Wind Turbine, Plant Control, and Distributed Wind Site Assessment

This SBIR topic focuses on low-cost sensor development for wind plant control and distributed wind site assessment. The next generation of land-based and offshore wind plants will rely heavily on system-level control to achieve optimized performance and provide various services to the grid. Achieving these objectives requires a new generation of integrated low-cost sensors and instrumentation that provide situational awareness of the operating plant environment and operational and response state of individual turbines [1]. For distributed wind resource assessment—where meteorological measurement campaigns are often cost-prohibitive—low-cost sensors could significantly advance the state of site assessment and improve project bankability, even if such sensors are somewhat less accurate than the current standard [2]. This SBIR topic seeks to develop lidar or other wind velocity sensors at a substantially lower cost than current technologies can achieve, with sufficient accuracy to perform distributed wind site assessment or inflow monitoring and control applications in utility-scale wind plants.

Questions – Contact: Mike Derby, Michael.Derby@ee.doe.gov

b. Sensor and Sensing Technologies for Offshore Subsea Cable Monitoring and Fault Detection System

Offshore wind plant transmission systems consist of miles of medium-voltage (MV) or high-voltage (HV) AC or DC subsea cables that transmit megawatt-hours of electricity from wind to the bulk electric grid onshore. The reliability of subsea cables is of significant importance because a cable failure could interrupt power delivery and potentially cause significant revenue losses. The state of subsea cables today is that they are not reliable. A recent report [3] shows that 14% of MVAC and 38% HVAC transmission systems experienced at least one failure. Accurate fault location is critical to successfully complete cable repairs. In the meantime, preventive maintenance is as important to identify incipient faults. The most widely-used technique for locating faults on subsea cables is the Time Domain Reflectometer (TDR). While TDR is the preferred technique for locating short circuits or open circuit faults, it is a lengthy process and the accuracy of pinpointing fault location is not optimal. Other techniques such as electroding and distributed temperature sensing system have serious limitations. This SBIR topic is seeking fast, accurate, and cost-effective sensors or sensing techniques that can identify potential cable issues or locate faults for subsea cables to improve electricity transmission from offshore wind plants.

Questions – Contact: Mike Derby, Michael.Derby@ee.doe.gov

c. Other

In addition to the above topic areas, WETO invites proposals for technology innovations that address technology gaps for distributed, land-based, and offshore wind [4, 5, 6, 7] with the potential to enable wind power to generate electricity in all 50 states cost competitively with other sources of generation.

This is an open call and areas of interest include, but are not limited to, the following:

- Technology solutions to mitigate environmental impacts for land-based and/or offshore wind plants [8, 9].
- Innovations in crane or other technologies that facilitate the adoption of "tall wind," for tower heights of 140m or higher [10, 11, 12].
- Application of Artificial Intelligence and/or Big Data Analysis methodologies to address wind turbine challenges such as SCADA data analysis for prognostic health management or intelligent assessment of environmental sensor data [10, 13, 14].

Questions – Contact: Mike Derby, Michael.Derby@ee.doe.gov

References:

1. Dykes, K. L., Hand, M. M., Lantz, E. J., et al, 2017, Enabling the SMART Wind Power Plant of the Future through Science-Based Innovation, National Renewable Energy Lab (NREL), No. NREL/TP-5000-68123, https://www.nrel.gov/docs/fy17osti/68123.pdf

2. Tinnesand, H., Sethuraman, L., 2019, Distributed Wind Resource Assessment Framework: Functional Requirements and Metrics for Performance and Reliability Modeling, National Renewable Energy Laboratory (NREL), NREL/TP-5000-72523. https://www.nrel.gov/docs/fy19osti/72523.pdf

3. Warnock, J., McMillan, D., Pilgrim, J., et al, 2019, Failure Rates of Offshore Wind Transmission Systems, Energies, 12. 2682. 10.3390/en12142682, https://eprints.soton.ac.uk/432854/1/energies_12_02682.pdf

4. Distributed Wind Energy Association, 2015, DWEA Distributed Wind Vision – 2015-2030 Strategies to Reach 30 GW of "Behind-the-Meter" Wind Generation by 2030, DWEA, http://distributedwind.org/wp-content/uploads/2012/08/DWEA-Distributed-Wind-Vision.pdf

5. Distributed Wind Energy Association, 2013, SMART Wind Roadmap: A Consensus-Based, Shared-Vision Sustainable Manufacturing, Advanced Research & Technology Action Plan for Distributed Wind, DWEA, http://distributedwind.org/wp-content/uploads/2016/05/SMART-Wind-Roadmap.pdf

6. U.S. Department of Energy, 2015, Wind Vision: A New Era for Wind Power in the United States, Office of Energy Efficiency & Renewable Energy, doi:10.2172/1220428, https://www.energy.gov/eere/wind/maps/wind-vision

7. U.S. Department of Energy, U.S. Department of Interior, 2016, National Offshore Wind Strategy: Facilitating the Development of the Offshore Wind Industry in the United States. Office of Energy Efficiency & Renewable Energy, http://energy.gov/sites/prod/files/2016/09/f33/National-Offshore-Wind-Strategy-report-09082016.pdf

8. Schwartz, S., 2019, Proceedings of the Wind-Wildlife Research Meeting XII, St. Paul, MN, November 28-30, 2018, Wildlife Workgroup of the National Wind Coordinating Collaborative by the American Wind Wildlife Institute, PNWWRM XII, https://www.nationalwind.org/wp-content/uploads/2019/04/WWRM-12-Proceedings-March-2019.pdf

9. Sinclair, K., DeGeorge, E., 2016, Wind Energy Industry Eagle Detection and Deterrents: Research Gaps and Solutions Workshop Summary Report, National Renewable Energy Laboratory (NREL), doi:10.2172/1248080, http://www.nrel.gov/docs/fy16osti/65735.pdf

10. U.S. Department of Energy, 2015, Enabling Wind Power Nationwide, U.S. Department of Energy, doi:10.2172/1220457, http://energy.gov/sites/prod/files/2015/05/f22/Enabling-Wind-Power-Nationwide_18MAY2015_FINAL.pdf

11. Lantz, E., Roberts, O., Dykes, K., 2017, Trends, Opportunities, and Challenges for Tall Wind Turbine and Tower Technologies, National Renewable Energy Lab (NREL), No. NREL/PR-6A20-68732, https://www.nrel.gov/docs/fy17osti/68732.pdf

12. Lantz, E., Roberts, O., Nunemaker, J., et al, 2019, Increasing Wind Turbine Tower Heights: Opportunities and Challenges, National Renewable Energy Laboratory (NREL), TP-5000-73629, https://www.nrel.gov/docs/fy19osti/73629.pdf

13. Monostori, L., Viharos, Z.J., Erdős, G., et al, 2009, AI Supported Maintenance and Reliability System in Wind Energy Production, The International Symposium on Methods of Artificial Intelligence AI-METH 2009, Gliwice, Poland, paper nr.: 20, https://www.researchgate.net/publication/281237483_Renewable_and_Sustainable_Energy_Reviews

14. Merizalde, Y., Hernández, L., Duque, O., et al, 2019, Maintenance Models Applied to Wind Turbines, A Comprehensive Overview, Energies, 12. 225. 10.3390/en12020225, https://www.mdpi.com/1996-1073/12/2/225

15. JOINT TOPIC: BIOENERGY AND ADVANCED MANUFACTURING TECHNOLOGY OFFICES: NOVEL UTILIZATION STRATEGIES FOR OCEAN PLASTIC WASTE

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Bioenergy Technologies Office (BETO) (https://energy.gov/eere/bioenergy) has a mission to help transform the nation's renewable and abundant biomass resources into cost-competitive, high-performance biofuels, bioproducts, and biopower. BETO is focused on forming partnerships with key stakeholders to develop technologies for advanced biofuels production from lignocellulosic and algal biomass as well as waste resources.

The Advanced Manufacturing Office (AMO) (https://energy.gov/eere/amo) collaborates with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies to drive U.S. energy productivity and economic competitiveness.

This Joint Topic brings together the Bioenergy Offices expertise with handling highly variable and dispersed feedstocks with the Advanced Manufacturing Office's expertise in developing highly energy efficient sustainable product manufacturing processes with a low lifecycle energy and environmental impact. It is responsive to the Assistant Secretary's priorities that fall within the production and recycling category of EERE's Circular Economy initiative.

Only a small fraction of the 60 million tons of plastic used in the United States is recycled, and an even smaller fraction is made into similar quality products as the original plastic, due to a loss in material properties during the recycling process [3]. This topic is focused on the rest of plastic that ends up in oceans and other waterways, causing increasing ecological damage. Development of technologies and products that can utilize the unique plastic feed stream will encourage ocean plastic collection and will improve the cost, carbon and energy efficiency of product manufacturing by retention and reuse of embodied energy in ocean plastics.

a. Novel Utilization Strategies for Ocean Plastic Waste

Economically viable strategies for the conversion of plastics collected from oceans and waterways into useful products face many challenges such as contamination and a lack of collection infrastructure. Development of technologies that can utilize this unique plastic feed stream will act as an incentive to advance collection and decontamination technology. This topic seeks conversion technologies which can utilize real or simulated streams of plastics collected from oceans and waterways to make useful products. The applicant must explain what makes their proposed product useful and any proposed end product must contain at least 50% ocean plastic. This solicitation specifically seeks applicants proposing technologies for converting waste plastics into a useful product (including mechanical, chemical, biochemical, or other conversion methods). It is expected that applicants may have programs that investigate multiple areas for addressing ocean plastic waste including plastic collection and end-product testing; however, awardees from this solicitation will only be funded for development of a conversion technology.

Applicants must:

- Discuss how their technology will address issues of mixed plastics and contamination unique to plastics recovered from waterways;
- Utilize real or simulated streams of plastics collected from oceans and waterways;
- Include preliminary life cycle assessment that addresses energy usage and emissions associated with the proposed technology;
- Include a preliminary cost analysis;
- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Include projections for price and/or performance improvements that are tied to a baseline;
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Questions – Contact: Melissa Klembara, Melissa.Klembara@ee.doe.gov or Jay Fitzgerald, Jay.Fitzgerald@ee.doe.gov

References:

1. U.S. Department of Energy, 2019, 2019 Project Peer Review, Bioenergy Technologies Office, https://www.energy.gov/eere/bioenergy/peer-review-2019

2. U.S. Department of Energy, 2017, 2017 Project Peer Review, Bioenergy Technologies Office, https://www.energy.gov/eere/bioenergy/peer-review-2017

3. U.S. Department of Energy, Multi-Year Program Plan, Bioenergy Technologies Office, https://www.energy.gov/sites/prod/files/2016/07/f33/mypp_march2016.pdf

16. JOINT TOPIC: BUILDING AND ADVANCED MANUFACTURING TECHNOLOGIES OFFICES: ADVANCED, AFFORDABLE THERMAL ENERGY STORAGE

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Residential and commercial buildings account for approximately 40% of the nation's total energy demand [1] and 75% of electricity use [2], resulting in an annual national energy bill totaling roughly $415 billion [3]. The U.S. Department of Energy's Building Technologies Office (BTO) (http://energy.gov/eere/buildings) is working in partnership with industry, academia, national laboratories, and other stakeholders to develop innovative, cost-effective, energy saving technologies that could lead to a significant reduction in building energy consumption and enable sophisticated interactions between buildings and the power grid. The rapid development of next-generation building technologies are vital to advance building systems and components that are cost-competitive in the market, to enable deep energy use reduction and lead to the creation of new business and industries. Widespread adoption of existing energy-efficient building technologies – and the introduction and use of new technologies – can reduce energy use in residential and commercial buildings by 50%, saving over $200 billion annually and reducing U.S energy-related greenhouse gas (GHG) emissions by roughly 20% compared to 2010 levels [4].

The Advanced Manufacturing Office (AMO) (http://energy.gov/eere/amo) collaborates with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies to drive U.S. energy productivity and economic competitiveness. AMO has a dual mission to develop technologies that reduce energy use in industry and also reduce the energy footprint of manufactured goods.

In this thermal energy storage (TES) Topic, BTO and AMO partner to solicit innovative research and development projects capable of addressing barriers to TES in buildings and in industry. It builds upon BTO's experience with innovative low temperature, high-performance and low-cost thermal energy storage materials and thermal circuit design as well as AMO's experience with thermal energy recovery, especially at high temperatures, and advanced materials manufacturing. Specifically, BTO's subtopic is focused on lower temperature phase change materials and thermochemical approaches for energy storage in buildings and novel approaches and control strategies for maximizing the capacity and utilization of the thermal storage system. AMO's subtopic has two areas of interest, one focused on higher temperature systems suitable for industrial process use and the second focused on phase change and thermoelectric materials manufacturing (including materials for harsh service conditions). While phase change materials are commercial, but need more research to lower cost and reduce barriers (such as handling corrosivity), thermochemical approaches are earlier stage and thus we plan to leverage the investment of the EERE energy storage cross cut in thermochemical energy storage for grid applications. This topic supports the priorities of the Assistant Secretary for EERE for inter-office cooperation to address (1) energy storage; (2) grid resiliency; (3) affordability; and (4) grid interactive buildings.

Heating and cooling in buildings and process heating in industry account for approximately half the energy use in these sectors. Hence, affordable thermal energy storage technologies could provide significant energy cost savings and increase grid resiliency. Furthermore, thermal energy storage for abundant "waste" heat or favorable ambient conditions readily available in both sectors could save several quadrillion Btus (Quads) of energy[3]. In the long run development of new thermal energy storage materials at all scales could transform building, industrial and product thermal energy use.

Proposals must:

- Propose a tightly structured program which includes thermal energy storage relevant technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Provide evidence that the proposer has relevant thermal energy storage experience and capability;
- Include projections for cost and/or performance improvements that are tied to a clearly defined baseline and/or state of the art products or practices;
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;

[3] Based on BTO SCOUT analysis of active insulation systems utilizing thermal mass and the ability to buffer and time-shift external thermal resources, there is potential for 1.47 Quads energy savings in residential buildings alone. Based on AMO analysis of 2014 EIA MECS data, there is potential for 0.5 Quads of industrial buildings energy savings alone.

- Include an energy savings impact and impact on building/facility-to-grid interaction as well as a preliminary cost analysis;
- Report all relevant performance metrics; and
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

The Phase I application should detail material, design and/or bench scale systems that are scalable to a subsequent Phase II prototype development. Applications must be responsive to the following subtopics. Applications outside of these subtopic areas will not be considered.

a. Thermal Energy Storage in Buildings

EERE seeks to accelerate the development of thermal energy storage materials that address limitations of current materials, such as high cost and low energy density, which contribute to their underutilization in buildings.

Energy storage materials that increase a building's thermal mass provide significant opportunities for reducing building energy consumption and the flexibility to time-shift demand on hourly time scales. By time-shifting consumption, building owners and occupants can gain the ability to consume energy during more favorable periods. Time-shifting may be done to reduce demand charges, to take advantage of time-of-use (TOU) rates, to better match photovoltaic (PV) output, to provide grid services, or to improve resilience in the face of power outages or other disruptions.

Paraffins are currently the most widely used phase change materials (PCMs) in building applications, yet their high cost, low volumetric energy capacities, and high combustibility are major barriers to their widespread acceptance [1]. These factors underline the need to shift the focus away from paraffinic PCMs. Two thermal energy storage classes of particular interest to BTO are: (1) Inorganic salt hydrate PCMs and (2) Thermochemical energy storage materials (TCMs), as are (3) technologies and approaches that allow for control over charging and discharging and optimize their use over the course of the year, not just a single season.

Under category 1: Inorganic salt hydrates and their eutectics have features that show great promise as primary PCMs for building applications. These features include high volumetric energy densities and suitable transition temperatures that can be achieved at low cost [2]. However, technical challenges remain which include excessive sub-cooling effect, incongruent melting and phase segregation during transition, corrosiveness, and difficulty in efficiently microencapsulating. Overcoming these barriers with low-cost and stable (e.g., chemically, physically, thermally) salt hydrate PCMs offer great value.

Under category 2: Thermochemical energy storage technologies are promising because they have potentially high energy densities and display the possibility of storing energy for long periods of time with negligible self-discharge [3]. Research in this field is nascent, though, leaving these technologies currently unavailable for building applications. As such, advances are needed to optimize their operating requirements including, but not limited to, operating temperatures closer to 50°C, multi-cycling efficiency, material and reactor cost, and appropriate systems design for building applications.

Under category 3: Of great interest are also novel dynamic approaches for using thermal mass (sensible) in building structures, actively coupling it with favorable exterior ambient conditions and the conditioned space to substantially reduce heating and cooling and provide load shifting and shedding, capabilities [4], as well as technologies and approaches that greatly improve the utilization and capacity of sensible, latent, and thermochemical thermal energy storage to decrease their levelized cost of storage per cycle. This includes tunable thermal technologies [5] with the ability to dynamically control their thermal conductivity, thus allowing control over the charging and discharging of the energy storage system, as well as PCMs with tunable phase transition temperature (T_t). Of particular interest are PCMs with T_t that can be dynamically adjusted, upon the addition of a control stimulus, to span the range of typical heating and cooling season temperature set points, though any thermal energy storage materials with $T_{t,max} - T_{t,min} \geq 2°C$ that can, for instance, keep PCMs in a "cooled" state until deployed to shift/shed peak loads would be valued.

For all categories, EERE is seeking advancements that make thermal storage more suitable for building applications. Preference will be given to non-toxic, noncombustible, low-odor materials with long lifetimes. Materials should aim for transition temperatures that can be safely deployed in building contexts. BTO is specifically interested in materials that can address the size and weight constraints that make some thermal storage technologies impractical for typical buildings.

Research activities should focus on improving the performance of materials with the highest potential to possess characteristics outlined in **Table 1**. While proposed approaches are not required to meet all the listed characteristics, they should demonstrate a path toward meeting the performance targets and characteristics laid out in **Table 1**. Approaches should also address any system integration considerations and other important process parameters specific to the material being proposed. All research should be on the highest caliber materials to yield the clearest possible results and potential for building applications.

Description	Target. and Characteristics	Clarifying Details
Phase Change Temperature	PCMs: 10-30°C TCMs: <50°C	Operating temperatures need to be appropriate for building applications. Each application group has different temperature requirements.
Large-scale availability and low price	<$15/kWh $_{thermal}$	The price of the raw material and the encapsulation process determine the cost of the thermal energy storage product. Materials should be low cost and abundant for scalability.
Volumetric energy capacity	PCMs: >100 kWh/m^3 TCMs: >250 kWh/m^3	
Thermal conductivity	>0.75 W/m·K	Impacts charging/discharging time. A suitable heat exchange is required.
Durability (Efficiency after thermal cycles and aging)	>90% after >7,500 cycles	Performance over several thermal cycles. Minimum of 7,500 cycles are required for minimum of 20 years.
Non-toxic, non-flammable, non-explosive and non-reactive	Requirement	Safety requirement for building applications
Non-corrosiveness	None or minimized	Compatibility with other materials, such as encapsulation materials
Volume variations during phase transition	Minimized	Alternatively may be addressed with appropriate system design

No phase segregation or separation	Minimized	Assure a long lifetime
Sub-cooling/super-cooling	Minimized; <2°C	To assure phase change transition when charging and discharging can proceed in a narrow temperature range with low hysteresis
Round-trip efficiency	Maximized	Ratio of thermal energy retained in the charging-discharging process.
Self-discharge	Minimized	Rate at which stored thermal energy is depleted as a function of time. Particularly relevant for TCMs.

Table 1: Targets and Characteristics for Next Generation Thermal Storage Materials for Buildings

Questions – Contact: Sven Mumme, sven.mumme@ee.doe.gov

b. Thermal Energy Storage in Industry and Relevant Materials Manufacturing

EERE seeks to accelerate the development of non-building applications of thermal energy storage materials that address limitations of current materials, such as safety issues/harsh service conditions, high cost, low efficiency. Except for industrial building heating and cooling applications covered in subtopic a, thermal energy of interest to industry and solar thermal applications is generally at a much higher temperature – both in terms of the minimum temperature of thermal energy (1) needed as inputs to industrial processes, and (2) available as "waste heat" to be stored. In addition, because industry has a more constant thermal and electrical load profile than residential or commercial buildings, it is more challenging to make cost-effective technologies that simply time-shift demand on hourly time scales. Although there are two broad areas of interest (below) AMO will consider other research relevant this subtopic.

- Industrial Thermal Energy Storage Systems: This area of interest focusses in industrial process heat which comprises 51% of industrial energy use, 95% of which derives from direct combustion or steam produced by fuel combustion and 34% of this heat is wasted [1]. Activities should focus on storage systems that increases the utilization of waste and renewable (e.g. solar, geothermal) heat by providing cost effective thermal storage options. Specifically, the focus is on improving the performance of systems for industrially relevant thermal storage with the highest potential to enable matching to the thermal energy using storage applications in **Table 2**[4]. Approaches should also address any system integration considerations and other important process parameters specific to the system/application being proposed.

Process Heating Operation	Description	Temperature Range (°C)	Estimated U.S. Energy Use in 2010 (TBtu)
Fluid heating, boiling, and distillation	Distillation, reforming, cracking, hydrotreating; chemicals production, food preparation	65-540	3,015

[4]A 2019 study [2] demonstrated PCM-TES implementation feasibility in energy-intensive industries in the medium- high temperature range. Specifically, it showed the achievability of significantly raising the temperature (from 700 to 865 °C) of industrial waste stream that started at 650 °C. The application studied was combustion air preheating for a ceramic furnace and the PCM investigated had a melting point of 885 °C.

Drying	Water and organic compound removal	90-370	1,178
Metal smelting and melting	Ore smelting, steelmaking, and other metals production	425-1650	968
Calcining	Lime calcining	815-1095	395
Metal heat treating and reheating	Hardening, annealing, tempering	90-1370	203
Non-metal melting	Glass, ceramics, inorganics manufacturing	815-1650	199
Curing and forming	Polymer production, molding, extrusion	150-1370	109
Other	Preheating; catalysis, thermal oxidation, incineration, softening, and warming	90-1650	1,049

Table 2. U.S. Industrial Process Heat. (Source: Thermal Energy Futures Task 2, Kurup et al. 2019)

- Materials manufacturing research for cost-effective, robust, environmentally friendly thermal storage materials for industrial processes: All types of storage are of interest (sensible, latent and thermochemical) Types of Materials of interest include PCM (encapsulated and not) Inorganic, molten salt, Ni-based alloys, stainless steels

Although they are currently the most costly alternative, TCMs are promising because of their long storage time (e.g. seasonal) and high capacity. Although they are still quite early stage, they will likely be a subject of research for grid applications and AMO hopes to leverage this research. R&D should focus on improving the performance of materials with the highest potential to possess characteristics outlined in **Table 3**. While proposed approaches are not required to meet all the Table 3 characteristics, they should demonstrate a path towards meeting the performance targets and characteristics laid out in **Table 3**. In addition to metrics in Table 3, proposed approaches should maximize thermal conductivity, durability (e.g. with aging and thermal cycling), and scale to industrially relevant volumes and masses [4].

Metric Description	Metric	Clarifying Details
Phase Change Temperature	PCMs: >>30°C TCMs: 60-1700°C	Operating temperatures need to be appropriate for industrial applications highlighted in Table 2 or for product manufacturing.
Large-scale availability and low price	<$25/kWh $_{thermal}$	Higher Temperature materials are generally more costly
Volumetric/Mass energy capacity	>100 kWh/m^3/ 120 kWh/t	

Table 3: Metrics for Next Generation Thermal Storage Materials for Non-Buildings Applications.

Questions – Contact: Tina Kaarsberg or Robert Gemmer, tina.kaarsberg@ee.doe.gov, bob.gemmer@ee.doe.gov

References:

1. U.S. Energy Information Administration, 2019, Table 2.1. Washington, DC: U.S. Department of Energy, Monthly Energy Review, https://www.eia.gov/totalenergy/data/monthly/#consumption

2. U.S. Energy Information Administration, 2019, Table 5.1. Washington, DC: U.S. Department of Energy, Electric Power Monthly, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_01

3. U.S. Energy Information Administration, 2019, Washington, DC: U.S. Department of Energy, Natural Gas Summary, http://www.eia.gov/dnav/ng/ng_sum_lsum_dcu_nus_a.htm

4. U.S. Department of Energy, 2019, Building Technologies Office Multi-Year Program Plan: Fiscal Years 2016-2020, https://www.energy.gov/sites/prod/files/2016/02/f29/BTO%20Multi-Year%20Program%20Plan%20-%20Final.pdf

References: Subtopic a:

1. Bland, A., Khzouz, M., Statheros, T., et al, 2017, PCMs for Residential Building Applications: A Short Review Focused on Disadvantages and Proposals for Future Development, Buildings 2017, 7, 78; doi:10.3390/buildings7030078, https://pure.coventry.ac.uk/ws/portalfiles/portal/12390425/buildings_07_00078_v2.pdf

2. Xie, N., Huang, Z., Gao, X., et al, 2017, Inorganic Salt Hydrate for Thermal Energy Storage, Applied Sciences, 7(12), 1317; doi:10.3390/app7121317, https://www.researchgate.net/publication/321910400_Inorganic_Salt_Hydrate_for_Thermal_Energy_Storage

3. International Renewable Energy Agency, 2013. Thermal Energy Storage: Technology Brief. Energy Technology Systems Analysis Programme, https://irena.org/documentdownloads/publications/irena-etsap%20tech%20brief%20e17%20thermal%20energy%20storage.pdf

4. Antretter, F., 2019, Active Insulation Systems, U.S. Department of Energy, Building Technologies Office Peer Review, https://www.energy.gov/sites/prod/files/2019/05/f62/bto-peer%E2%80%932019-ornl-active-insulation-systems.pdf

5. Prasher, R., Dames, C., Jackson, R., 2019, Solid State Tunable Thermal Energy Storage and Switches for Smart Building Envelopes, U.S. Department of Energy, Building Technologies Office Peer Review, https://www.energy.gov/sites/prod/files/2019/05/f62/bto-peer%E2%80%932019-lbnl-nrel-solid-state-tunable-tes.pdf

References: Subtopic b:

1. NREL, 2019, Report on Industrial Energy Storage, Energy Systems Integration Newsletter: September 2019, https://www.nrel.gov/esif/esi-news-201909.html

2. Royo, P., Acevedo, L., Garcia-Armingol, T., et al, 2019, High-temperature PCM-based Thermal Energy Storage for Industrial Furnaces Installed in Energy-intensive Industries, Energy, 173, 1030e1040, https://www.researchgate.net/publication/331186991_High-temperature_PCM-based_thermal_energy_storage_for_industrial_furnaces_installed_in_energy-intensive_industries

3. McMillan, C., and M. Ruth, 2019. "Using facility-level emissions data to estimate the technical potential of alternative thermal sources to meet industrial heat demand", Applied Energy, Volume 239, 1 April 2019, Pages 1077-1090. https://www.sciencedirect.com/science/article/abs/pii/S0306261919300807?via%3Dihub

4. Teller O., Nicolai, J.P., Lafoz, M., et al, 2017, Joint EASE/EERA Recommendations for a European Energy Storage Technology Development Roadmap towards 2030. European Association for Storage of Energy,

https://www.eera-set.eu/wp-content/uploads/2017.01.16_Update-of-the-EASE-EERA-ES-Technology-Development-Roadmap_for-public-consultation.pdf

5. Energy Efficiency & Renewable Energy, 2017, Solar for Industrial Process Heat Analysis, https://www.nrel.gov/analysis/solar-industrial-process-heat.html

17. JOINT TOPIC: WATER, WIND, AND ADVANCED MANUFACTURING TECHNOLOGIES OFFICES: AFFORDABLE, GRID-FRIENDLY, HIGH-TORQUE DIRECT-DRIVE GENERATORS

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Office of Energy Efficiency and Renewable Energy's Water Power Technologies Office (WPTO) (http://energy.gov/eere/water) conducts early-stage research and development to strengthen the body of scientific and engineering knowledge enabling industry to develop new technologies that increase US hydropower and marine and hydrokinetic (MHK) generation. Hydropower and MHK technologies generate renewable electricity that supports domestic economic prosperity and energy security while enhancing the reliability and resiliency of the US power grid.

The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy's Wind Energy Technologies Office (WETO) (https://energy.gov/eere/wind) drives innovation through research, development, and testing of advanced wind energy technologies. The portfolio focuses on land-based, offshore, and distributed wind, as well as integration with the grid.

The Office of Energy Efficiency and Renewable Energy's Advanced Manufacturing Office (AMO) (https://energy.gov/eere/amo) collaborates with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance the global competitiveness of the United States.

This Joint Topic is aimed at R&D on cost-effective power conversion and conditioning of utility-scale wind, marine hydrokinetic (MHK) and low-head hydroelectric energy resources for electricity generation. These renewable energy technologies typically require low-speed and high torque drives and demand compact form and high reliability due to their location. Further improvements and cost reductions can be achieved by providing compact power conditioning systems with functionality that enables increasing mechanical torque-density of the machine and improve grid integration. An enabling technology for achieving these goals is the emerging class of high-voltage high-frequency power semiconductor devices based on wide bandgap semiconductor materials, and the associated advanced power electronics manufacturing practices.

In this Topic, WPTO, WETO, and AMO seek applications for the development of innovative and impactful technologies that will support a strong water power, wind power, and power electronics manufacturing sector and supply chain in America, while producing turbines that keep pace with the rising domestic and global demand for affordable renewable energy.

Applications must:

- Propose a tightly structured program which includes technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;

- Include projections for price and/or performance improvements that are tied to a recent baseline (i.e. Roadmap targets and/or state of the art products or practices);
- Explicitly and thoroughly differentiate the proposed innovation with respect to state-of-the art existing commercially available products or solutions;
- Include a preliminary cost analysis;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Applications must be responsive to the following subtopic. Applications outside this subtopic will not be considered.

a. Compact Power Conditioning Systems for High-Torque, Low-Speed Machines

Very high-power (7-12 MW) off-shore wind-turbines are being deployed to exploit the benefit of reduced cost of electricity that comes with increased machine size, and even higher-power wind turbines continue to be developed [1]. These very large turbines use a very low-speed, high-torque direct-drive machine (no speed reduction gears) and a full power electronic drive train to meet the extremely challenging size and weight requirements imposed by the wind turbine tower and to meet the grid operational interface requirements for large generators. WETO recently announced new projects to develop superconducting generator technology that will further reduce the size and weight of generator machines for very large wind turbines, enabling them to scale to even higher power (> 17 MW) and enabling further reduction in the cost of electricity [2]. Similar increasing power and remote application trends are emerging in low-head hydropower and MHK generators that also demand increasingly high torque and compact machines.

The purpose of this subtopic is to address the challenges of manufacturing the power conditioning system (PCS) to meet the needs for electronic drive of the high-power high-torque machines, meet the large generator grid integration requirements, and meet the size and weight reduction needs for the turbine location and assembly. The high-power high-torque turbine machines require:

- Medium-voltage drive (3.3 – 10 kV) to reduce current requirements;
- High-frequency switching to mitigate high fault currents (that would result from the low impedance of high-power low-torque machines) without using bulky passive filters; and
- Advanced topologies and controls to provide the extremely low harmonics needed to prevent eddy current heating near the cryogenic windings of superconducting machines.

The PCS must also provide a high-voltage (> 69 kVac) operational interface meeting large generator grid interconnection requirements without use of bulky 60 Hz transformers and/or filters, and must provide multi-port power for the turbine positioning motors. A new generation of PCSs for wind and MHK turbines can be enabled by emerging high-voltage, high-frequency switching power transistors made with wide-bandgap (WBG) semiconductor materials. The DOE AMO DOE Next Generation Electric Machine – Megawatt-Class Motors program [3] is addressing advanced high-speed motor drive technology based on WBG power electronics that can be extended to address challenges of high-torque, low-speed generators.

Applicants must define: Phase I – advanced PCS approaches including topology, technology and controls to address challenges of advanced very high-power wind turbines and marine hydrokinetic (MHK) turbines; Phase II – experimental validation of advanced approaches; and, if appropriations permit, a Phase III demonstration of 1 MW wind turbine PCS that is scalable to 20 MW and manufactured in the US.

Return to Table of Contents

Questions – Contact: Rajesh Dham, rajesh.dham@ee.doe.gov, Michael Derby, michael.derby@ee.doe.gov, Allen Hefner allen.hefner@ee.doe.gov

References:

1. Stromsta, K.E., 2019, GE Finishes First Nacelle for 12MW Offshore Wind Turbine, Green Tech Media, https://www.greentechmedia.com/articles/read/ge-finishes-first-nacelle-for-12mw-haliade-x-offshore-wind-turbine.

2. U.S. Department of Energy, 2019, Department of Energy Selects Projects to Develop High-Efficiency, Lightweight Wind Turbine Generators for Tall Wind and Offshore Applications, Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/eere/articles/department-energy-selects-projects-develop-high-efficiency-lightweight-wind-turbine.

3. U.S. Department of Energy, Electric Machines, Office of Energy Efficiency & Renewable Energy, https://www.energy.gov/eere/amo/electric-machines.

Return to Table of Contents

PROGRAM AREA OVERVIEW: OFFICE OF ENVIRONMENTAL MANAGEMENT

With the end of the Cold War, the Department of Energy (DOE) is focusing on understanding and eliminating the enormous environmental problems created by the Department's historical mission of nuclear weapons production. The DOE's Office of Environmental Management (EM) seeks to eliminate these threats to human health and the environment, as well as to prevent pollution from on-going activities. The goals for waste management and environmental remediation include meeting regulatory compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and expediently deploying technologies to accomplish these activities. While radioactive contaminants are the prime concern, hazardous metals and organics, as defined by the Resource Conservation and Recovery Act (RCRA), are also important.

DOE has approximately 91 million gallons of liquid waste stored in underground tanks and approximately 4,000 cubic meters of solid waste derived from the liquids stored in bins. The current DOE estimated cost for retrieval, treatment and disposal of this waste exceeds $50 billion to be spent over several decades. The highly radioactive portion of this waste, located at the Office of River Protection (Hanford Reservation), Idaho, and Savannah River sites, must be treated and immobilized, and prepared for shipment to a future waste repository.

DOE also manages some of the largest groundwater and soil contamination problems and subsequent cleanup in the world. This includes the remediation of 40 million cubic meters of contaminated soil and debris contaminated with radionuclides, metals, and organics [1]. The Office of Subsurface Closure focuses on four areas of applied research including the Attenuation-Based Remedies for the Subsurface Applied Field Research (Savannah River Site), the Deep Vadose Zone Applied Field Research (Hanford Site), and the Remediation of Mercury and Industrial Contaminants Applied Field Research (Oak Ridge Site).

For additional information regarding the Office of Environmental Management priorities, please visit us on the web at https://www.energy.gov/em/office-environmental-management.

18. NOVEL MONITORING CONCEPTS IN THE SUBSURFACE

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: NO

Current long-term monitoring and maintenance strategies and technologies are available to verify cleanup performance. This Initiative is aimed at developing and deploying more cost effective long-term strategies and technologies to monitor closure sites (including soil, groundwater and surface water) with multiple contaminants (organics, metals and radionuclides) to verify integrated long-term cleanup performance. Long-term monitoring and maintenance will soon become one of the largest projected cost centers in the overall lifecycle of both Environmental Management; moreover, costs associated with the implemented systems will extend into future Legacy Management. Much of the cost is associated with frequent analyses of contaminants in a large number of monitoring wells. Such measurements are often expensive and the resulting datasets are inefficient and inadequate for meeting long term monitoring objectives. The approach to long-term monitoring is a systems based approach which includes 4 broad themes: spatially integrated monitoring tools, onsite and field monitoring tools & sensor, engineered diagnostic components, and integrated risk management & decision support tools.

We propose to solicit the best concepts from industry on the following theme:

A. onsite and field monitoring tools and sensors,
B. Other

The topic for 2020 is as follows:

a. Onsite and Field Monitoring Tools and Sensors

As part of our current initiative to develop a process to close pump and treat systems we will need new methods of long term monitoring to assure protection of human health and the environment especially when enhanced attenuation remedies have been used which can create secondary sources which need to be monitored to show that they remain robust through time. Onsite and field monitoring tools and sensors that are part of broad spatially integrated monitoring system would reduce significantly laboratory analysis costs. Example technologies include field analysis sensors, deployed sensors, geophysical monitoring, screening tools and other concepts to reduce the number of lab-based analyses or to reduce sampling costs (e.g., reduce investigation derived waste). This would also include identification of indicator or surrogate parameters and documentation that such parameters would provide equal or better documentation of environmental protection to concentration measurements.

Contacts: Latrincy Bates, 301-903-7654, Latrincy.Bates@em.doe.gov

b. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Contacts: Latrincy Bates, 301-903-7654, Latrincy.Bates@em.doe.gov

References:

1. U.S. Department of Energy, 2012, Scientific Opportunities for Monitoring at Environmental Remediation Sites (SOMERS): Integrated Systems-Based Approaches to Monitoring, Pacific Northwest National Laboratory (PNNL), Document #PNNL-21739, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-21379.pdf

PROGRAM OFFICE OVERVIEW – OFFICE OF FOSSIL ENERGY

The U.S. Department of Energy's Office of Fossil Energy (FE) plays a key role in helping the United States meet its continually growing need for secure, reasonably priced and environmentally sound fossil energy supplies. FE's primary mission is to ensure the nation can continue to rely on traditional resources for clean, secure and affordable energy while enhancing environmental protection.

Fossil fuels are projected to remain the mainstay of energy consumption (currently 80% of U.S. energy consumption) well into the next century. Consequently, the availability of these fuels, and their ability to provide clean, affordable energy, is essential for global prosperity and security. As the nation strives to reduce its reliance on imported energy sources, FE supports R&D to promote the secure, efficient and environmentally sound production and use of America's abundant fossil fuels in both existing and new infrastructure.

For additional information regarding the Office of Fossil Energy priorities, visit https://www.energy.gov/fe/mission.

19. ADVANCED TURBINES TECHNOLOGIES

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The DOE-FE and NETL is supporting the research and development of turbine-based technologies applicable to fossil fuels including coal derived synthesis gas, coal derived hydrogen and natural gas. The turbine-based machinery and turbine based subsystems developed through the Advanced Turbines Program will have direct application to coal gasification processes where coal derived synthesis gas or hydrogen are produced. Additionally, because the modifications required for a turbine-based heat engine to accept coal syngas or natural gas are small and manageable, and the market for natural gas applications is robust, natural gas will be considered the developmental fuel in this program.

The Advanced Turbines Program comprises portfolio of gas turbine-focused projects which address a wide variety of technical topics (including combustion, aerodynamics/heat transfer, and advanced materials) by conducting cutting edge R&D that is also relevant to the gas turbine industry to support advanced technologies that can increase energy efficiency, reduce emissions, and provide additional performance benefits. Over the long history of the Advanced Turbines Program, the technical topics of interest have been continually updated as R&D results have successfully addressed technical needs while new technical challenges emerge. Thus, the program portfolio continually seeks to conduct timely, highly scientific R&D across a variety of technical topics which are also of industrial relevance.

Grant applications are sought in the following subtopics:

a. Low Cost, High-Yield Advanced Manufacturing (AM) Techniques for Ceramic Matrix Composite Applicable to Combustion Turbine Hot Gas Path Components

This topic area seeks to develop and evaluate advanced manufacturing techniques of fabricating low cost, high yield ceramic matrix composites (CMCs) that can withstand temperatures exceeding 3,100°F for turbine hot gas path components and achieve a combined cycle energy efficiency of more than 65%. CMCs are known to improve impact durability by making propagation of cracks more difficult than in bulk ceramics due to their composite construction. Fabrication of CMCs is expensive and time consuming, and application in large scale production is limited due to their high cost and a complex manufacturing process. There are a limited number of CMC manufacturers in the market today, which coupled with the cost of CMC substrates, makes this area particularly challenging.

Grant applications are sought for research and development of reliable, low-cost AM techniques to fabricate ceramic matrix composites (CMC), that can be subsequently made readily available to researchers in this area. Applicants under this AOI are encouraged to identify ways to improve the matrix in CMCs, with or without developing the fiber. Cooling hole designs are not of interest in Phase I. The proposed scope of work should be realistic in terms of the time and budget allowed for a Phase 1 project. Although fiber development is not of interest under this topic, material development technologies targeting different types of reinforcements may be considered as an exploratory subject.

Proposed CMCs should improve the performance, cost, reliability, and endurance of turbine components/systems. Responsive projects must include the validation of concepts at a laboratory scale and emphasize achieving transformational performance and efficiencies while being pragmatic from a cost-effective and manufacturability perspective, to be considered for future commercialization in higher-temperature gas turbine components.

Questions – Contact: Patcharin Burke, Patcharin.Burke@netl.doe.gov

b. Sensors for Turbine Applications

Grant applications are sought for the research, development, and implementation of sensors for combustion turbine systems including, but not limited to, the development of non-intrusive high temperature and pressure sensors. Applicants are challenged to produce time and location accurate measurements of pressure, temperature, heat flux, strain, and species that can operate in extreme conditions and difficult to access locations within a turbine.

The applicant must clearly explain why the proposed sensor(s) are necessary for improving the performance, cost, and reliability, of turbine components or related systems such as: pressure gain combustion, oxy-combustion, and direct/in-direct supercritical CO_2. Sensors must be capable of real-time, continuous operation at temperatures ranging from 1200°C to 1700°C. Sensor materials and designs must be carefully selected to exhibit stable operation and robustness to survive harsh environments relevant to advanced combustion turbines. The applicant must identify sensing strategies that provide stable and rapid responses within temperature and pressure ranges of interest.

Approaches of interest include, but are not limited to, direct deposition sensors, high temperature fiber-based sensors, optical sensors and sensing methods coupled with machine learning. Sensor technologies leading to durable operation throughout typical turbine component lifetimes or major maintenance inspections of the hot gas path (on the order of 24,000-48,000 hours) are encouraged. Approaches that are not of interest include sensor technologies that are not minimally intrusive or sensor technologies that produce time-weighted measurements (i.e. sensors that do not measure in real-time).

Questions – Contact: Mark Freeman, Mark.Freeman@netl.doe.gov

Return to Table of Contents

c. Low Flow, High Pressure Ratio Compressors Providing Ancillary Support to Supercritical Carbon Dioxide Power Cycles

Supercritical carbon dioxide (sCO_2) power cycles have gained significant interest for various power generation applications due to potential performance and cost benefits over steam Rankine power cycles. Minimizing leakage from sCO_2 turbomachinery has been identified as a notable means for maximizing thermal efficiency of sCO_2 power cycles. Improved seals are being developed and will help mitigate this problem, but it is desirable to recover and recompress leakage to reduce the efficiency penalty that is associated with its loss.

Applications are being sought for the research, development, and implementation of low flow, high pressure ratio compressors that are capable of efficiently recompressing sCO_2 turbomachinery leakage to provide ancillary support to sCO_2 power cycles. Due to the nature of leakage, the compressor will have internal zones that operate below the cycle pressure (the maximum inlet pressure should be 75 psi, with a minimum outlet pressure of 1000 psi). Possible designs include, but are not limited to, high speed centrifugal compressors, linear motor driven piston compressors, and novel combinations of different compressor technologies. The applicant must clearly describe how the technology will be implemented into the sCO_2 power cycle to improve cycle performance and the impacts that recompression will have on the performance of the power cycle. Applications should focus on the design and integration of components (compressors, intercoolers, balance of plant (BOP) equipment) that will enable recompression and should also discuss strategies for sourcing and containing sCO_2 leakage.

Questions – Contact: Matt Adams, Matthew.F.Adams@netl.doe.gov

d. Expansion Joint Technology for High Temperature and Pressure Conditions in sCO_2 Power Cycles

Economical and efficient heat transfer technologies applicable to high-temperature, high-pressure conditions are a common requirement for advanced fossil energy power generation systems. For example, power cycles based on supercritical CO_2 are targeting temperatures in excess of 700°C and pressures of 250-300 bar to enable highly efficient performance. In these cycles, piping and joints between process equipment such as the turbine, heat exchange components, or recuperator, are subject to extreme stresses due to the temperature cycling, high pressures, and exposure to supercritical fluid. Existing joining materials are capable of high temperature (800°C) or high pressure (720bar), but not both simultaneously. Joining technologies that can handle these extreme conditions would open up design space and allow for some design freedom that could lead to lower plant costs and a therefore a lower cost of electricity.

Grant applications are sought for research and development for expansion joints that are capable of safe and stable operation in conditions relevant to the high-temperature (700-800°C) and high pressure (300 bar) conditions found in supercritical CO_2 applications. Joining technology should be scalable to sizes typical to industrial plants ranging from 8" to 24", robust to pressure upsets, and capable of withstanding continuous exposure to supercritical CO_2. Target applications should focus on extraction of heat from fossil-fired combustion heat sources into working fluids or internally between working fluids within a steam or supercritical CO_2 power cycle.

Questions – Contact: Matt Adams, Matthew.F.Adams@netl.doe.gov

e. Other

In addition to the specific subtopics listed, FE invites grant applications in other areas that fall within the scope of topic description provided above.

Questions – Contact: Patcharin Burke, Patcharin.Burke@netl.doe.gov

References: Subtopic a:

1. Zheng, M., Parbat, S.N., Yang, L., et al, 2018, Fabrication and Characterization of Additive Manufactured Nickel-Based Oxide Dispersion Strengthened Coating Layer for High-Temperature Application, J. Eng. Gas Turbines Power, 140 (6): 062101, https://asmedigitalcollection.asme.org/gasturbinespower/article-abstract/140/6/062101/474649/Fabrication-and-Characterization-of-Additive?redirectedFrom=fulltext

2. Zhou, Y., Wang, X., Xiang, H., et al, 2016, Theoretical prediction, preparation, and mechanical properties of YbB6, a candidate interphase material for future UHTCf/UHTC composites, Journal of the European Ceramic Society, 36 (3571-3579), https://www.sciencedirect.com/science/article/abs/pii/S0955221916301030

3. Halbig, M., Jaskowiak, M., Kiser, J., et al, Evaluation of Ceramic Matrix Composite Technology for Aircraft Turbine Engine Applications, NASA Glenn Research Center, Cleveland, OH 44135, https://arc.aiaa.org/doi/abs/10.2514/6.2013-539

4. M. Rosso, 2006, Ceramic and metal matrix composites: Routes and properties, Journal of Materials Processing Technology, Volume 175, p. 364-375, https://www.sciencedirect.com/science/article/pii/S092401360500419X

References: Subtopic b:

1. Tejedor, T., Singh, R., Pilidis, P., 2013, Maintenance and Repair of Gas Turbine Components, Modern Gas Turbine Systems, Woodhead Publishing Series in Energy, p. 565-634,10.1533/9780857096067.3.565, https://www.sciencedirect.com/book/9781845697280/modern-gas-turbine-systems

2. Yu, Y., Mikkilineni, A.K., Killough, S.M., et al, 2019, Direct-Write Printed Current Sensor for Load Monitoring Applications, IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), https://ieeexplore.ieee.org/document/8791597

3. Liu, Y., Frediani, L., Harsh, K., et al, 2018, PhaseDOE12-14c: Advanced Ceramic Materials and Packaging Technologies for Realizing Sensors Operable up to 1800 Celsius in Advanced Energy Generation Systems, U.S. Department of Energy Office of Science and Technical Information, https://www.osti.gov/biblio/1470679-phasedoe12-advanced-ceramic-materials-packaging-technologies-realizing-sensors-operable-up-celsius-advanced-energy-generation-systems

4. Torres, J., Mireles, J., Choudhuri, A., et al, Metal 3D Printing of Low-NOX Fuel Injectors with Integrated Temperature Sensors., U.S. Department of Energy, doi:10.2172/1489120, https://www.netl.doe.gov/sites/default/files/event-proceedings/2017/crosscutting/20170320-Track-A/20170320_1600A_Presentation_FE0026330_UTEP.pdf

5. Dong, L., Tittel, F.K., Li, C. et al, 2016, Compact TDLAS based sensor design using interband cascade lasers for mid-IR trace gas sensing. Optics Express, doi:10.1364/OE.24.00A528, https://www.osapublishing.org/oe/abstract.cfm?uri=oe-24-6-A528

Return to Table of Contents

References: Subtopic c:

1. Bidkar, R.A., Sevincer, E., Wang, J., et al, 2016, Low-Leakage Shaft End Seals for Utility-Scale Supercritical CO2 Turboexpanders, ASME Turbo Expo, Seoul, South Korea, https://asmedigitalcollection.asme.org/GT/proceedings-abstract/GT2016/49781/V05AT15A019/240410

2. Brun, K., Friedman, P., Dennis, R., 2017, Fundamentals and Applications of Supercritical Carbon Dioxide (sCO2) Based Power Cycles, Woodhead Publishing, Cambridge, MA, https://www.elsevier.com/books/fundamentals-and-applications-of-supercritical-carbon-dioxide-sco2-based-power-cycles/brun/978-0-08-100804-1

3. Bidkar, R.A., Singh, R., Mann, A., et al, 2016, Conceptual Designs of 50MWe and 450MWe Supercritical CO2 Turbomachinery Trains for Power Generation from Coal, Part 1: Cycle and Turbine, The 5th International Symposium - Supercritical CO2 Power Cycles, https://www.researchgate.net/publication/309478837_Conceptual_Designs_of_50MWe_and_450MWe_Supercritical_CO2_Turbomachinery_Trains_for_Power_Generation_from_Coal_Part_1_Cycle_and_Turbine

4. Bidkar, R.A., Singh, R., Mann, A., et al, 2016, Conceptual Designs of 50MWe and 450MWe Supercritical CO2 Turbomachinery Trains for Power Generation from Coal, Part 2: Compressors, The 5th International Symposium - Supercritical CO2 Power Cycle, https://www.researchgate.net/publication/309478837_Conceptual_Designs_of_50MWe_and_450MWe_Supercritical_CO2_Turbomachinery_Trains_for_Power_Generation_from_Coal_Part_1_Cycle_and_Turbine

5. Moullec, Y.L., Conceptual study of a high efficiency coal-fired power plant with CO2 capture using a supercritical CO2 Brayton cycle, Energy, vol. 49, pp. 32-46, 2013, https://www.sciencedirect.com/science/article/abs/pii/S0360544212007840

References: Subtopic d:

1. Advanced Turbines, National Energy Technology Laboratory, https://netl.doe.gov/coal/turbines

2. Brun, K. Friedman, P., Dennis, R., 2017, Fundamentals and Applications of Supercritical Carbon Dioxide (sCO2) Based Power Cycles, Woodhead Publishing, Cambridge, MA, https://www.sciencedirect.com/book/9780081008041/fundamentals-and-applications-of-supercritical-carbon-dioxide-sco2-based-power-cycles

3. Bidkar, R.A., Singh, R., Mann, A., et al, 2016, Conceptual Designs of 50MWe and 450MWe Supercritical CO2 Turbomachinery Trains for Power Generation from Coal, Part 1: Cycle and Turbines, The 5th International Symposium - Supercritical CO2 Power Cycles, San Antonio, Texas, https://www.researchgate.net/publication/309478837_Conceptual_Designs_of_50MWe_and_450MWe_Supercritical_CO2_Turbomachinery_Trains_for_Power_Generation_from_Coal_Part_1_Cycle_and_Turbine

20. CARBON CAPTURE TECHNOLOGIES

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

For the foreseeable future, fossil fuels (coal and natural gas) will continue to play a critical role in powering the Nation's electricity generation, especially for base-load power plants. Enabling this power production in a carbon constrained environment will require carbon capture and storage from power plant flue gases. In

order to prevent 2°C warming by 2100, there has been a great deal of discussion and information published regarding Negative Emission Technologies (NETs). In fact, in 2019, the National Academies of Science published a study called "Negative Emissions Technologies and Reliable Sequestration: A Research Agenda". Included within NETs are several different technologies including: 1) Land management to increase carbon in coastal ecosystems (also referred to as coastal blue carbon); 2) Forest management or agricultural property management to increase carbon in these ecosystems; 3) Bioenergy with carbon capture and sequestration (also referred to as BECCS); 4) Carbon mineralization; and 5) Direct air capture (also referred to as DAC). DAC uses chemical processes to facilitate removal of the CO_2 directly from the air.
For almost two decades, DOE's Office of Fossil Energy (FE) has been developing technologies to remove CO_2 from point sources burning fossil fuels. The R&D has focused on both advanced materials and processes to lower the cost of capturing these emissions. The overall cost reductions have focused on decreasing the parasitic penalty of these systems (OpEx) and, more recently, the large capital investment (CapEx). Synergies exist between the work that FE has been doing on CO_2 point source capture and the work needed to be done on DAC. Although the concentration of point source CO_2 emissions is higher, ranging from approximately 14% to 4% for coal-based and gas-based systems, respectively, the simulation-based engineering, materials and processes that have been used for point source capture might also, with optimization, be amenable to DAC at CO_2 concentrations of 0.04%.

Grant applications are sought in the following subtopics:

a. Novel Materials or Processes to Support Transformational Carbon Capture Technologies

Among the objectives of the Carbon Capture Program is to support the development of transformational technologies for fossil fuel-based power plants with CO_2 capture with 95% purity and with a cost of electricity at least 30% lower than a supercritical PC with CO_2 capture, or approximately $30 per tonne of CO_2 captured. The technologies can include both materials and processes used for advanced carbon capture. Grant applications are sought for novel materials including membranes, sorbents, solvents or hybrid materials that have NEVER been examined for the purpose of carbon capture. The results of a literature review will be necessary to demonstrate the novel nature of the proposed material.

Additionally, grant applications are also sought for novel process concepts that will lead to an improvement in the overall cost of carbon capture systems. Applications must show that the materials or processes have the potential to provide a significant improvement towards the aforementioned objectives of the Carbon Capture Program. Capture technologies can be applicable to both coal and natural gas-based flue gas. This subtopic area directly relates to harnessing American energy resources safely, efficiently and in an environmentally sound manner.

Questions – Contact: Katharina Daniels, Katharina.Daniels@netl.doe.gov

b. Direct Air Capture

Current estimates for DAC suggest that it can cost between $300 - $1,500/tonne of CO_2 captured. It is well known that pollution removal costs typically increase as the pollutant concentration decreases. With CO_2 concentrations being 100 times smaller than emissions from a gas-fired power plant, the challenge is developing cost effective technologies to capture CO_2 from air.

Grant applications are sought for the development of new materials that have an ability to remove low concentrations of CO_2 from the air. As material development is a large and complex field, simulation-based engineering may be needed to inform researchers of the best candidate materials and/or optimizations that can be done to improve on any one class of materials to achieve removal of CO_2 from low concentration streams.

Questions – Contact: Katharina Daniels, Katharina.Daniels@netl.doe.gov

c. Process Intensification for Carbon Capture Systems

Application of Process Intensification to Carbon Capture Systems: Processes being developed for CO_2 capture employ a number of standard unit operations, such as gas-liquid contactors (e.g., gas absorbers and strippers), gas-solid contactors (e.g., packed and moving beds), gas-separation membranes, heat exchangers, pumps, and compressors; all of which may be suitable for process intensification, by integrating two or more of these operations within a single piece of equipment. Example combinations include absorption/desorption, adsorption/desorption, compression/gas separation, and membrane reactors.

DOE has on-going projects for CO_2 capture focused on the development of absorption systems employing liquid solvents, adsorption systems employing solid sorbents, and gas-separation membrane systems. Applicants are encouraged to focus their proposals toward development and/or testing of optimized hybrid and/or integrated approaches that synergistically complement each other to significantly improve the performance and lower the costs of carbon capture. New solvent, sorbent, or membrane materials development should not be a part of any proposal submitted and will be considered non-responsive to the sub-topic.

Questions – Contact: Katharina Daniels, Katharina.Daniels@netl.doe.gov

d. Other

In addition to the specific subtopics listed, FE invites grant applications in other areas that fall within the scope of topic description provided above.

Questions – Contact: Katharina Daniels, Katharina.Daniels@netl.doe.gov

References: Subtopic a:

1. National Energy Technology Laboratory, 2017, Carbon Capture Program Fact Sheet, U. S. Department of Energy, p. 4. http://netl.doe.gov/sites/default/files/2017-11/Program-115.pdf

2. U. S. Energy Information Administration, 2019, EIA Annual Energy Outlook 2019, U. S. Department of Energy, http://www.eia.gov/outlooks/aeo/

3. National Energy Technology Laboratory, Office of Fossil Energy, 2019, Cost and Performance Baseline for Fossil Energy Plants, Volume 1, Revision 4, U.S. Department of Energy, http://netl.doe.gov/projects/files/CostAndPerformanceBaselineForFossilEnergyPlantsVol1BitumCoalAndNGtoElectBBRRev4-1_092419.pdf

References: Subtopic b:

1. Consensus Study Report, 2019, Negative Emissions Technologies and Reliable Sequestration: A Research Agenda, National Academics of Science, Engineering, Medicine, http://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda

Return to Table of Contents

2. Intergovernmental Panel on Climate Change, Global Warming of 1.5ºC, http://www.ipcc.ch/sr15/

References: Subtopic c:

1. National Energy Technology Laboratory, Carbon Capture Program, http://netl.doe.gov/coal/carbon-capture

21. CARBON STORAGE TECHNOLOGIES

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

STORAGE R&D—Storage R&D involves both applied laboratory- and pilot-scale research focused on developing new technologies and systems for geologic storage of carbon dioxide (CO_2). The Carbon Storage Program has a mission of developing technologies for commercial readiness beginning in 2025 that ensure safe, secure, efficient, and affordable CO_2 injection and containment in storage complexes in diverse geologic settings. Critical to this mission is reducing uncertainty and risk, providing a field validated commercial toolbox, providing regulators a technical foundation for producing science-based regulations, and enabling operators to meet regulatory requirements.

To advance Carbon Capture and Storage (CCS) toward commercial deployment priority research areas for the Carbon Storage Program include improved wellbore integrity and fluid mitigation assessment; enhancements to subsurface monitoring technologies at reduced cost; advancements in intelligent monitoring systems developed or adapted for commercial-scale CCS sites; and transformational tools, sensors and methods for accurately characterizing the subsurface including faults, fracture networks, and fluid flow.

Grant applications must include a succinct discussion of the potential technical and economic advantages of the proposed technology, as compared to existing state-of-the-art systems.

Grant applications are sought in the following subtopics:

a. Integrating Technologies to Lower Uncertainties in Carbon Storage Complexes

Accurate monitoring and tracking are required for carbon dioxide (CO_2) storage complexes to satisfy operators, regulators, and local stakeholders that the injectate is moving as anticipated, is not leaking or trespassing, is safely contained, and poses no future threats. Operating permits for geologic storage projects under the Safe Drinking Water Act and Clean Air Act require this monitoring to account for stored CO_2 and to ensure that potable groundwater sources and sensitive ecosystems are protected. This monitoring can be made up of multiple technologies focused on specific aspects, such as plume location, plume conformance, caprock integrity, above-zone reservoirs, groundwater quality, soil gases, or atmospheric conditions. The resulting observations are usually used individually to history match a simulation or model to the observed condition.

Every technology possesses specific advantages and limitations with respect to its sensitivity and spatial resolution. Some tools are restricted to “point measurements” from a wellbore. For instance, downhole pressure measurements respond quickly to changing conditions but may give limited information related to the source of the change. Time-lapse logging measurements made from inside a well can have fine vertical resolution and be highly sensitive to CO_2 saturation, and be unable to measure properties more than a few inches or feet from the borehole. Conversely, surface seismic can monitor large areas, but typically lacks fine detail both vertically and horizontally and is generally unable to resolve small to moderate CO_2 saturation changes. Other technologies are currently in the development phase (e.g., electromagnetics, resistivity) that could fill gaps in resolution or sensitivity. However, they are not single solutions and have their own strengths and weaknesses.

Grant applications are sought to provide methods that combine monitoring technologies of varying physics, resolutions, and/or temporal or length scales to greatly decrease uncertainties in measuring plume (CO_2 or differential pressure) location and to verify containment. Methods to integrate existing and future technologies are sought, so that the strengths of each can be leveraged to overcome the limitations of individual methods. Focus should be placed on combining methods (existing and novel) to monitor large areas (ideally all) of the storage complex at higher resolution. Development of new sensors is not of interest for this opportunity.

Questions – Contact: Kyle Smith, Kyle.Smith@netl.doe.gov

b. Developing Graphical User Interface and Software Distribution Platform for an Integrated Model for Geologic Carbon Storage Containment and Leakage Risk Assessment

A significant barrier to large-scale deployment of geologic carbon storage (GCS) is the lack of confidence by some GCS stakeholders that environmental risks – those associates with potential leakage to overlying resources or the atmosphere, and induced seismicity – are small and manageable. To address this challenge the U.S. Department of Energy (DOE) established the National Risk Assessment Partnership (NRAP) - a research partnership of five contributing national laboratories (Los Alamos National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, National Energy Technology Laboratory, and Pacific Northwest National Laboratory) to develop the technical basis, computational tools, and protocols for science-based, quantitative assessments of containment effectiveness and environmental risks at geologic carbon storage sites. A primary product of NRAP research is the NRAP open-source integrated assessment model (NRAP-Open-IAM) – an open-source software product that enables quantification of containment effectiveness and leakage risk at storage sites. While the NRAP contains state-of-the-art GCS analysis capabilities, its user interface and software distribution paradigm are not sufficiently developed to meet a “market-ready” standard that would be required for wider application by industry and regulatory stakeholders with diverse backgrounds. *The goal requested is to advance the NRAP-Open-IAM to make it market-ready through enhanced user-operability.*

NETL is seeking applicants to develop an improved user interface with pre- and post-processing functionality and results display for the NRAP-Open-IAM that will improve the usability of advanced tool functionality to perform quantitative risk assessments and support critical GCS containment assurance and leakage risk performance analyses. Additionally, the successful applicant will develop an effective means of delivering a fully functional product (NRAP-Open-IAM code and user interface) to the end user (e.g., through containerized distribution).

To ensure the usability and commercial applicability of the NRAP-Open-IAM user interface and software distribution platform, the successful applicant will engage (in coordination with the NRAP technical leadership) with potential users / GCS stakeholders to test the developed user interface product and product distribution paradigm.

Questions – Contact: Kyle Smith, Kyle.Smith@netl.doe.gov

Return to Table of Contents

c. Other

In addition to the specific subtopics listed, FE invites grant applications in other areas that fall within the scope of topic description provided above.

Questions – Contact: Kyle Smith, Kyle.Smith@netl.doe.gov

References: Subtopic a:

1. National Energy Technology Laboratory, Carbon Storage Program, https://netl.doe.gov/coal/carbon-storage

2. National Energy Technology Laboratory, 2019, 2019 Proceedings – Addressing the Nation's Energy Needs Through Technology Innovation – 2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting – Subsurface Sessions, U.S. Department of Energy, https://netl.doe.gov/node/9042

3. National Energy Technology Laboratory, Advanced Storage R&D, https://www.netl.doe.gov/coal/carbon-storage/advanced-storage-r-d

References: Subtopic b:

1. National Energy Technology Laboratory, 2017, National Risk Assessment Partnership Fact Sheet, U.S. Department of Energy, p. 4. https://netl.doe.gov/sites/default/files/rdfactsheet/R-D179_0.pdf

2. Bacon, D.H., Yonkofski, C., Brown, C.F., et al, 2019, Risk-Based Post Injection Site Care and Monitoring for Commercial-Scale Carbon Storage: Reevaluation of the FutureGen 2.0 Site using NRAP-Open-IAM and DREAM, International Journal of Greenhouse Gas Control, https://www.sciencedirect.com/science/article/abs/pii/S1750583618310016

3. Pawar, R., Bromhal, G., Dilmore, R., et al, 2016, The National Risk Assessment Partnership's Integrated Assessment Model for Carbon Storage: A Tool to Support Decision Making Amidst Uncertainty, International Journal of Greenhouse Gas Control. Volume 52, Pages 175–189. http://dx.doi.org/10.1016/j.ijggc.2016.06.015

4. Lackey, G., Vasylkivska, V.S., Huerta, N.J., et al, 2019, Managing Well Leakage Risks at a Geologic Carbon Storage Site with Many Wells, International Journal of Greenhouse Gas Control, Volume 88, Pages 182-194, https://www.sciencedirect.com/science/article/abs/pii/S1750583619302476

22. CARBON UTILIZATION PROGRAM

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

With over 5 billion metric tons of CO_2 emissions in the United States in 2017, utilization and conversion of CO_2 into value-added chemicals, fuels, polymers, building materials, and other carbon-based products represents a key economic opportunity. CO_2 utilization technologies can reduce overall CO_2 emissions and offset CO_2 capture costs by generating valuable products. In addition to CO_2 emissions from electric power, industrial CO_2 emissions provide an opportunity for utilization of CO_2 under different conditions and concentrations and may prove to be more applicable for CO_2 utilizations technologies. The objective of the DOE carbon utilization R&D effort is to develop technologies with the potential to transform CO_2 in value-added products in an efficient, economical and environmentally-friendly manner. Using CO_2 to create products may require less energy, less reagents, and generate less waste than production from petroleum or natural gas feedstocks, which can lower life-cycle carbon footprints. CO_2 conversion pathways, even within tailored catalytic systems, can be energy intensive due to the high thermodynamic stability of CO_2, and will require novel and innovative technologies to become commercially viable.

Grant applications are sought in the following subtopics:

a. Plasma Technologies

Plasma technologies have many advantages over traditional CO_2 conversion pathways and may provide a unique and economical process for the utilization of anthropogenic CO_2. Plasma technologies provide gas activation by energetic electrons instead of heat, allowing thermodynamically difficult reactions, such as CO_2 splitting, to occur with reasonable energy costs. Plasma technologies can also be easily switched on and off which is compatible with intermittent renewable energy and load-following applications. The most common types of plasma reported in the literature are dielectric barrier discharges (DBDs), microwave (MW), and gliding arc (GA); however, other types, such as radiofrequency, corona, glow, spark, and pulsed electron beam (PEB), have also been studied in the literature. Depending on the type of plasma, different CO_2 conversions and energy efficacies have been reported. In terms of energy efficiency, a target of at least 60 percent energy efficiency has been suggested for plasma CO_2 conversion to be competitive with other technologies. Plasma tends to be very reactive and not selective in the production of targeted compounds. Therefore, plasma CO_2 conversion technologies may need a catalyst to increase selectivity and produce targeted compounds. Low conversion of CO_2 could also require postreaction separation of the products from the reactants and may be cost prohibitive. Proposals are sought to convert CO_2 to high value chemicals or fuels using plasma technologies in an economically viable process, overcoming challenges associated with energy efficiency, CO_2 conversion and selectivity. These proposals should seek to understand reaction mechanisms, reactive intermediate species, and incorporate modular designs.

Questions – Contact: Naomi O'Neil, Naomi.Oneil@netl.doe.gov

b. Carbon Utilization - Production of Solid Carbon Materials

The prevalence and use of diverse carbon-based products (i.e. carbon black, nanotubes, and fibers) has steadily grown in our modern society. The initial demand for carbon products were isolated to in niche markets such as aerospace and aircraft manufacturing, which could validate high costs for products like carbon fibers. Applications for carbon-based products into new markets include carbon fibers for wind energy and automotive industry, and graphite in lithium-ion electric vehicle batteries. However, factors such as high manufacturing costs, large energy requirements, and damaging environmental impacts limit wide-scale adoption. Emerging industries are developing pathways to reduce the carbon in CO_2 to create pure carbon products. Processes that convert CO_2 to high-value carbon composites must use an economically viable process and overcome challenges associated with energy efficiency, CO_2 conversion and selectivity. The DOE is seeking proposals to understand the influence of catalysts on carbon product development in terms of selectivity and carbon conversion efficiencies in thermo-catalytic or electro-catalytic systems. Specifically, the DOE is seeking proposals which create synthetic graphite, since the United States lacks production of natural solid carbon graphite and has classified graphite as a critical material. In addition, proposals that address methods to mitigate interlaminar shear failure within carbon composites are also sought.

Questions – Contact: Naomi O'Neil, Naomi.Oneil@netl.doe.gov

c. Other

In addition to the specific subtopics listed, FE invites grant applications in other areas that fall within the scope of topic description provided above.

Questions – Contact: Naomi O'Neil, Naomi.Oneil@netl.doe.gov

References: Subtopic a:

1. Office of Fossil Energy, 2014, Carbon Storage Technology Program Plan, U.S. Department of Energy, p. 70, http://www.netl.doe.gov/File%20Library/Research/Coal/carbon-storage/Program-Plan-Carbon-Storage.pdf

2. Bogaerts, A., Neyts, E.C., 2018, Plasma Technology: An Emerging Technology for Energy Storage, ACS Energy Letters, Vol. 3, Issue 4, p. 1013-1027, https://pubs.acs.org/doi/abs/10.1021%2Facsenergylett.8b00184

3. Puliyalil, H., Jurković, D.L., Dasireddy, V., et al, 2018, A Review of Plasma-assisted Catalytic Conversion of Gaseous Carbon Dioxide and Methane into Value-added Platform Chemicals and Fuels, RSC Advances, Vol. 8, Issue 48, p. 27481-27508, https://pubs.rsc.org/en/content/articlehtml/2018/ra/c8ra03146k

4. Snoeckx, R., Bogaerts, A., 2017, Plasma Technology–A Novel Solution for CO 2 Conversion?, Chemical Society Reviews, Vol. 46, Issue 19, p. 5805-5863, https://pubs.rsc.org/en/content/articlehtml/2017/cs/c6cs00066e

References: Subtopic b:

1. Das, S., Warren, J., West, D., et al, 2016, Global Carbon Fiber Composites Supply Chain Competitiveness Analysis, Clean Energy Manufacturing Analysis Center, https://www.nrel.gov/docs/fy16osti/66071.pdf

2. Olson, D., 2019, Mineral Commodity Summaries, U.S. Geological Survey, https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/mcs-2019-graph.pdf

23. CROSSCUTTING TECHNOLOGIES

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The *Crosscutting Research Program* is unique in its ability to foster and support enabling technologies across multiple fossil-based energy systems and operational platforms. Resources that are common to several research areas are leveraged to achieve strategic goals and objectives as well as application-specific performance metrics. In many cases, processes and materials that advance one technology platform may well have application in another with little to no modification.

Crosscutting Research leverages the latest technology trends such as artificial intelligence, advanced manufacturing, and high-performance computing. These advanced capabilities accelerate progress toward addressing the challenges facing today's fossil power plants and realize the next generation of fossil energy technology platforms. The technologies developed improve power plant efficiency, reduce operating and maintenance costs, and help maintain a reliable and resilient energy infrastructure.

This program also accelerates the development of science and engineering-based solutions across a range of technology maturities from initial concept to market delivery through the creation of strategic partnerships with stakeholders who share an interest in maximizing the value of our nation's fossil resources. In this context, the SBIR program is a key component to developing and commercializing technology to realize program goals and public benefit.

Grant applications are sought in the following subtopics:

a. Supply Chain Enhancements for Fossil Energy Alloy Production

Supply chain innovation is critical to the development of next generation fossil energy (FE) power generation technologies, and in improving the performance and reliability of existing FE power plants.

Improved methods to manufacture alloys used for large steam cycle components in pulverized coal and natural gas combined cycle power plants are sought. Gas Turbine applications are not of interest.

Nickle superalloys offer improved cycle performance with enhanced flexibility; however, costs remain a barrier to wide-spread implementation. For these superalloys, the goal of this topic is improved material yield, improved material quality, and/or decreased component cost.

For existing plants, ferritic and austenitic stainless steels are of central interest. They suffer under cyclic loading conditions particularly at joints and dissimilar metal welds. Failure mechanisms include thermal fatigue, corrosion-fatigue, creep, corrosion, oxidation, and erosion – with relative predominance dependent on a host of material- and system-specific factors. For existing plants, the goal of this topic is to develop a material, model, or repair technology that increases plant life and reliability and decreases Operations and Maintenance (O&M) costs.

Applications should address key barriers to producing a robust domestic supply chain. This work should take the form of supply chain assessment, market analysis, industrial manufacturing trials, end-user value proposition demonstration, and technoeconomic analysis. Industrial supply chain partners are required. Applicants must specify the manufacturing process or component of interest, relevant specification for material performance (microstructure, mechanical properties, etc.), proposed manufacturing approach, and summary of critical fabrication issues. Suggested topics include, but are not limited to the following:

- **Ingot Cost Reduction:** Reduce the cost of producing basic ingots from their alloying elements without loss of product quality (chemical purity, microstructure and physical properties (mechanical strength)).
- **Surface Technologies:** Materials and processes for enhancing the resistance of base alloy materials to environmental constituents.

Questions – Contact: Richard Dunst, Richard.Dunst@netl.doe.gov

b. Automated Plant Component Inspection, Analysis, and Repair Enabled by Robotics

Inspection of power plant components is challenging, time-consuming, and in some cases not possible due to process and safety constraints. However, non-destructive evaluation (NDE) techniques allow for a depth of component health assessment not possible with on-line monitoring via state-of-the-art sensor technology. Robotics may offer the opportunity to conduct NDE of components not otherwise possible during planned and unplanned outages. For example, robots may allow for inspection in hard to reach places or under conditions that would not be safe for a human. Additionally, location-precise inspection could enable the automation of inspection data logging and analysis, which otherwise would be less meaningful. Finally, if components are damaged, it may be possible to repair them using guided or autonomous robotic cleaning, welding, surface treatments, or even component replacement via advanced manufacturing techniques.

In recent years, the ability to inspect power plant components using high-resolution visual imaging via aerial drones and robots that climb walls or crawl through pipes has become available. There is a need to go beyond visual inspection and advance the state of the art. There is also a need for robots, in the case of crawlers, that can navigate on non-ferrous surfaces and pipes.

NERC Generating Availability Data System (GADS) analysis shows that boilers are the leading cause of US coal power plant fleet forced outages. Components such as waterwalls, superheaters, reheaters, and economizers can become damaged over time and these boiler components are the largest cause of failure and forced outages.

Successful Applicants will develop a robot that will integrate several technologies (e.g., data fusion, cleaning, NDE, repair) for application within coal-based power generation units. Automatic inspection data gathering and analysis should be anticipated in the robotic sensor package. Data fusion is desired such that offline data (should the robotic inspection and repair be attained during plant downtime) can be used along with on-line data to provide a complete, real-time reflection of component health to power plant operators. Integration of these types of data is not required; however, data generated must be in the form that can be used by the M&D center or other market-driven end-user application.

The Applicant should define the power plant coal-boiler component and anticipated challenge or opportunity addressed, including a succinct description of the value proposition to a power plant operator/owner. Primary target applications must be coal boilers; however, technologies with additional applicability to other fossil power plant applications are acceptable.

R&D must be performed and explained in such a way that there is an advancement from the current state of the art. Exploratory research and development that integrates new technology with existing technology is acceptable.

Questions – Contact: Jessica Mullen, Jessica.Mullen@netl.doe.gov

c. Real-time Monitoring of Selenium, Mercury, and Arsenic in Coal Power Plant Effluent Streams

Selenium, mercury, and arsenic have been identified as toxic pollutants in the Clean Water Act (CWA) list of Priority Pollutants 307(a)(1) which are further referenced and defined in the Code of Federal Regulations 40 CFR 401.15. Effluent Guidelines are national regulatory standards issued by the U.S. Environmental Protection Agency (EPA) for wastewater discharged to surface waters and municipal sewage treatment plants.

In 2015, U.S. EPA finalized new effluent limitation guidelines (ELGs) pertaining to total dissolved solids, mercury, selenium, nitrates, and arsenic in effluent streams from steam power generation plants. In 2017, the US EPA issued a stay on the November 2018 compliance date to further review the regulations. Revised ELGs are expected to be announced soon; however, as of the date of the writing of this topic, they have not been released.

The capture, measurement, and monitoring of selenium in power plant effluent streams remains a needed area for further research. The amount and form of selenium in power plant wastewaters can vary depending upon changes in fuel or flue gas particulate and desulfurization control equipment operation. The removal of selenium from power plant wastewaters using conventional means can be problematic in many instances. Biological systems are subject to upset conditions if the bacteria doing the work die off, or if changes in loading, pH, or temperature exceed limits. Further, some types of chemical/physical treatment may not be effective for selenate removal. Therefore, it is important to have online, real-time monitoring of selenium, especially liquid-phase selenium. And, although treatment techniques for mercury and arsenic are more reliable, there remains a need for on-line measurement and monitoring in real time.

The use of available commercial online monitoring analyzers can be problematic. Advances are needed to eliminate plugging caused by supersaturation of sulfates, operate with higher suspended solids content, improve the analyzer availability and reliability, and eliminate other interferences in the effluent stream.

Applications are sought to develop novel concepts for real-time, on-line monitoring in power plant effluent streams. The primary focus is on selenium in the liquid-phase; however, applications that can also measure mercury and arsenic are a plus. The analyzer should be capable of long-term operation without corrosion from dissolved chlorides, plugging, and without the need for frequent calibration, upkeep, or highly-skilled users. Analyzers should be suitable for use in the presence of suspended solids and capable of measuring total selenium along with the primary speciated forms of selenium: selenate and selenite. The analyzer should target near-term field testing and be capable of measuring selenium at concentrations, flow rates, pressures, and temperatures that are present in power plant wastewaters. A benchtop (non-continuous) analyzer would be acceptable instead of an on-line, continuous monitor if the sensitivity, ease of use, reliability, and maintenance for the bench-top unit would be dramatically improved as compared to an on-line analyzer. Applications proposing a benchtop analyzer must outline the potential benefits as compared to an on-line unit.

Analyzers should provide data in a form that can be used by power plant operators. Data are to be conveyed in a method that will minimize cyber-vulnerabilities while enabling flexible water treatment system operability. An assessment must be performed to identify cybersecurity risks and mitigate them. Once developed, the analyzer technology should be red-team tested by an independent third party in the demonstration environment, using project funds, to confirm the developed product is cyber secure.

Questions – Contact: Jessica Mullen, Jessica.Mullen@netl.doe.gov

d. Other

In addition to the specific subtopics listed, FE invites grant applications in other areas that fall within the scope of topic description provided above.

Questions – Contact: Maria Reidpath, Maria.Reidpath@netl.doe.gov

References: Subtopic a:

1. DOE Crosscutting Workshop on Developing a Domestic Supply Chain for High Temperature Steam Cycles, 2018 https://edx.netl.doe.gov/group/view_digital_notebook/crosscutting-research/9871fd01-f380-4b9a-9b05-5b891b9f7b5b

2. DeBarbadillo J., et al., 2016, Alloy 740H – Development of Fittings Capability for AUSC Applications, 8th International Conference on Advances in Materials Technology for Power Plants, Albufeira, Portugal,

https://s3.amazonaws.com/v3-app_crowdc/assets/d/da/da77d8e83c0796b6/File_4_FINAL_-_deBarbadillo_-_Alloy_740H_%E2%80%93_Development_of_Fittings_Capability_for_AUSC_Applications.original.1473277539.pdf

3. White, B., 2019, Crosscutting Research, Program Overview, Proceedings from 2019 Annual Project Review Meeting, https://www.netl.doe.gov/sites/default/files/2019-05/2019_Annual_Reports/1%20NETL%20DOE%20Crosscutting_Annual%20Review%20Meeting_2019_Final%20Draft.pdf (accessed 10/11/2019)

4. Smith, D., 2017, Boiler Maintenance and Upgrades – Attacking Tube Failures, Power Engineering, Power Engineering, Issue 2, Volume 108, https://www.power-eng.com/2004/02/01/boiler-maintenance-and-upgrades-mdash-attacking-tube-failures/

5. Pfeuffer, S., 2009, Update: Benchmarking Boiler Tube Failures, Power, https://www.powermag.com/update-benchmarking-boiler-tube-failures/

References: Subtopic b:

1. Speight, J.G., 2013, Coal-Fired Power Generation Handbook, Scrivener Publishing, ISBN: 978-1-118-20846-5 https://www.wiley.com/en-us/Coal+Fired+Power+Generation+Handbook-p-9781118208465

2. Dongke, Z., 2013, Ultra-supercritical Power Plants – Materials, Technologies, and Optimization, Woodhead Publishing Ltd., https://www.amazon.com/Ultra-Supercritical-Coal-Power-Plants-Technologies/dp/0857091166

3. Al-Qadeeb, F., 2005, Tubing Inspection Using Multiple NDT Techniques, 3rd MENDT – Middle East Nondestructive Testing Conference & Exhibition, Saudi Aramco, Dhahran, Saudi Arabia, https://www.ndt.net/article/mendt2005/pdf/p18.pdf

4. Sieben, A., 2015, Inspection of Boiler Tubes and Boiler Tube Welds: Overview of NDT Techniques, Acuren, http://www.wcblrbac.org/files/9314/4708/1384/Acuren_Boiler_Tube_Inspection_Oct__28_2015.pdf

5. Sadek, H.M., 2006, NDE technologies for the examination of heat exchangers and boiler tubes – principles, advantages and limitations, Insight, Vol 48, No. 3, https://www.ndt.net/article/insight/papers/insi_48_3_181.pdf

6. Mitsubishi Hitachi Power Systems, 2019, MHPS to Use Drones for Inspecting Power Plant Boilers, Mitsubishi Hitachi Power Systems Press Release, http://www.mhps.com/news/20190312.html

7. Gecko Robotics Industrial Inspections, 2019, Robots, https://www.geckorobotics.com/technology/robots

8. Quest Integrity, 2019, Inspection Services, https://www.questintegrity.com/services/inspection-services/

9. North American Electric Reliability Corporation, 2019, Generating Availability Data System (GADS) Conventional Plant Data https://www.nerc.com/pa/RAPA/gads/Pages/GeneratingAvailabilityDataSystem-(GADS).aspx

References: Subtopic c:

1. United States Environmental Protection Agency (EPA), website, Effluent guidelines. https://www.epa.gov/eg

2. United States Environmental Protection Agency (EPA), Effluent Guidelines, EPA to Reconsider ELG Rule. https://www.epa.gov/newsreleases/epa-reconsider-elg-rule

3. Reinsel, M., 2016, Selenium Removal Technologies: A Review, Apex Engineering, https://www.wateronline.com/doc/selenium-removal-technologies-a-review-0001

4. Smith, K., Lau, A., Vance, F.W., 2009, Evaluation of Treatment Techniques for Selenium Removal, 2009 International Water Conference Proceedings, IWC 09-05, pp. 75-92. http://toc.proceedings.com/07490webtoc.pdf

5. Conference Proceedings: Selenium Summit 2018. EPRI, Palo Alto, CA: 2019. 3002017039 https://www.epri.com/#/pages/product/3002017039/?lang=en-US

6. Field Evaluation of Online Selenium and Mercury Monitors: Application to Flue Gas Desulfurization Wastewater Treatment Process Control. EPRI, Palo Alto, CA: 2017. 3002010796 https://www.epri.com/#/pages/product/3002010796/?lang=en-US

24. FUEL CELLS

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The mission of the Solid Oxide Fuel Cells (SOFC) program is to enable the efficient generation of low-cost electricity for (a) 2nd Generation natural gas-fueled SOFC distributed generation (DG) systems and modular, coal-fueled systems and (b) Transformational coal or natural gas-fueled utility-scale systems with carbon capture and sequestration (CCS). The program supports the overarching goals of the Clean Coal and Carbon Management Research Program (CCCMRP) through the collaboration between the R&D that addresses the technical and economic barriers to commercial viability and the development and deployment of SOFC power systems that validates those solutions.

Grant applications are sought in the following subtopics:

a. **Sensors for Solid Oxide Fuel Cell (SOFC) Applications**

   Grant applications are sought for the research, development, and implementation of SOFC system sensors including the development of multivariable sensors that can detect multiple gases with a single sensor or the inclusion of an intelligent sensing option. The sensors are used to monitor the aggressive environments found within the cells, stacks, or balance of plant (BOP) that can affect SOFC performance (e.g. fuel, oxidant, temperature, pressure, and humidity).

   The applicant must clearly explain why the proposed sensor(s) are necessary in improving the performance, cost, reliability, and endurance of SOFC components/systems. Sensors must be capable of real-time operation at temperatures ranging from 600°C to 900°C. Sensor materials and designs must be carefully selected to ensure a safe, reliable and continuous operation of the SOFC and they must exhibit stable operation and robustness to survive SOFC environments, and be compact enough to fit within SOFC systems. The applicant must identify sensing strategies that provide stable and rapid responses within concentration ranges of interest for SOFC operating environments. Approaches of interest include, but are not limited to, fiber optic and ceramic-based sensors. Sensor technologies leading to durable operation throughout typical SOFC lifetimes (on the order of 40,000 hours) are encouraged. Approaches that are not of interest include sensor technologies that are not minimally intrusive or sensor technologies that produce time-weighted measurements (i.e. sensors that do not measure in real-time).

Questions – Contact: Steven Markovich, Steven.Markovich@netl.doe.gov

b. Additive Manufacturing for Solid Oxide Fuel Cell (SOFC) Cell, Stack, or Balance of Plant (BOP) Components

Additive manufacturing (AM) has been identified as a potentially attractive option for use in the manufacture of high temperature performance components used in SOFC systems. AM enables the design and synthesis of materials whose microstructure and properties allow for the construction of components that not only maintains structural integrity but also offers the ability to perform multiple functions.

Grant applications are sought for research and development of AM techniques to fabricate SOFC cells, stacks, or BOP components. The applicant must clearly state how AM techniques can be used to design and generate SOFC structures and components with functionality and characteristics that exceed the performance requirements of state of the art SOFC materials or SOFC or BOP components. A complete description of the manufacturing process required to achieve the proposed architectures should be provided to facilitate analysis of potential cost issues and implementation complexity. Applications can focus on individual cell components, a complete SOFC cell, or a BOP component. A clear plan must be presented that outlines how individual or entire SOFC cell or stack or BOP component architectures would be fabricated and implemented and discusses performance attributes.

Questions – Contact: Debalina Dasgupta, Debalina.Dasgupta@netl.doe.gov

c. Other

In addition to the specific subtopics listed, FE invites grant applications in other areas that fall within the scope of topic description provided above.

Questions – Contact: Steven Markovich, Steven.Markovich@netl.doe.gov

References: Subtopic a:

1. Ohodnicki, P.R., 2017, Optical Fiber Based Sensors for Future Fossil Energy Applications, *National Energy Technology Laboratory,* https://netl.doe.gov/sites/default/files/event-proceedings/2017/crosscutting/20170322-Track-A/20170322_1500A_Presentation_Ohodnicki_NETL.pdf

2. Fergus, J., 2008, A Review of Electrolyte and Electrode Materials for High Temperature Electrochemical CO2 and SO2 Gas Sensors, Science Direct, Vol. 134, Issue 2, https://www.sciencedirect.com/science/article/pii/S0925400508004863

3. Ohodnicki, P.R., Buric, M.P., Brown, T.D., et al, 2013, Plasmonic nanocomposite thin film enabled fiber optic sensors for simultaneous gas and temperature sensing at extreme temperatures, Nanoscale, 5 (19) 9030-9039, https://pubs.rsc.org/en/content/articlelanding/2013/nr/c3nr02891g#!divAbstract

4. Yu, L., Bonnell, E., Homa, D., et al, 2016, Observation of temperature dependence of the IR hydroxyl absorption bands in silica optical fiber, Optical Fiber Technology, 30, 1-7, https://pubs.rsc.org/en/content/articlelanding/2013/nr/c3nr02891g#!divAbstract

References: Subtopic b:

1. Khatri-Chhetri, P., Datar, A., Cormier, D., Novel SOFC Processing Techniques Employing Printed Materials, Advances in Materials Science for Environmental and Energy Technologies: Ceramic Transactions, Volume 236, 129-139, http://onlinelibrary.wiley.com/doi/10.1002/9781118511435.ch14/summary

2. National Energy Technology Laboratory, Solid Oxide Fuel Cell, http://www.netl.doe.gov/research/coal/energy-systems/fuel-cells

25. TRANSFORMATIVE POWER GENERATION

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The Transformative Power Generation Program aims to advance science, engineering, and technology by inventing, integrating, maturing, and commercializing coal combustion power technologies and systems to enhance the nation's energy production and protect the environment for future generations. The program develops technologies to improve performance and extend the life of existing power plants. Research also focuses on next generation modular coal-fired power plants providing stable power generation with operational flexibility and high efficiency, as well as advanced combustion technologies such as oxy-combustion and chemical looping combustion—technologies that provide options for coal-fired power generation in a carbon-constrained future. The program uses a multi-pronged and coordinated approach to identify and perform research through in-house research and development (R&D), as well as cost-shared R&D with external partners in academia, industry, and other national laboratories. Transformative Power Generation technologies will be market-driven with the best technologies, growing deployment opportunities in an increasingly challenging power generation market.

Grant applications are sought in the following subtopics:

a. Advanced Hybrid Fossil Energy Systems with Energy Storage

The Coal FIRST program is actively supporting several advanced technologies to enable a new generation of fossil energy systems for electricity generation that are more flexible to respond to the increasingly variable need for dispatchable power. One approach for enabling greater flexibility is to couple advanced fossil energy systems with energy storage systems; however, a comprehensive comparison of potential storage technologies requires detailed, dynamic models that can be coupled with power plant models and optimized over anticipated operating scenarios.

DOE and NETL have created an advanced, open source computational platform through the Institute for the Design of Advanced Energy Systems (IDAES). The IDAES platform supports conceptual design, process integration, and process dynamics to enable the rigorous design and optimization of new energy technologies.

Proposals are sought which will develop models of potential energy storage systems within the IDAES computational platform and use those models to determine optimal approaches for integrating storage

Return to Table of Contents

technologies with potential Coal FIRST power generation systems. The models must be developed within the IDAES computational platform, leveraging existing IDAES models and capabilities.

Questions – Contact: Matt Adams, Matthew.F.Adams@netl.doe.gov

b. Improving the Performance of the Existing Coal Fleet

Originally designed for baseload operation, the U.S. fleet of coal-fired power plants are being increasingly forced to cycle their load or operate under minimum load conditions in response to variable or low electricity demand. Plant efficiency is typically reduced by such off-design operation while overall reliability is negatively impacted by the higher thermal, mechanical, and chemical stresses incurred from frequent load changes. Advanced process systems engineering tools can be used to identify operating conditions and load following trajectories that optimize the complex tradeoffs between short-term (e.g., efficiency, ramp rate) and long-term (e.g., useful equipment lifespans) objectives.

DOE and NETL have created an advanced, open source computational platform through the Institute for the Design of Advanced Energy Systems (IDEAS). The IDAES platform enables a complete workflow that includes

- rigorous analysis of current power plant operation,
- development of high-fidelity equipment models (using 1st-principles, data-driven, and hybrid approaches), and
- comprehensive system-wide optimization after linking together the predictive models within a unified framework.

Proposals are sought which will develop and validate computational models of coal-fired power plants and apply those models to identify actionable recommendations aimed at improving the efficiency, controllability, and/or reliability of an existing facility or facilities. The models must be developed within the IDAES computational platform, leveraging existing IDAES models and capabilities.

Questions – Contact: Steven Markovich, Steven.Markovich@netl.doe.gov

c. Modeling and Validation of Heat Transfer for Indirect SCO_2 Coal-Fired Boilers

The supercritical carbon dioxide (sCO_2) power cycle operates in a manner like other turbine cycles, but it uses CO_2 as the working fluid in the turbomachinery. The cycle is operated above the critical point of CO_2 so that it does not change phases, but rather undergoes drastic density changes over small ranges of temperature and pressure. Supercritical CO_2-based power cycles have shown the potential for increased heat-to-electricity conversion efficiencies, high power density, and simplicity of operation compared to existing steam-based power cycles. The sCO_2 power cycle utilizes small turbomachinery, is fuel- and/or heat-source neutral, and efficient.

DOE and NETL are developing highly efficient and lower cost indirectly-heated power cycles that surpass the performance of advanced ultra-supercritical steam. However, R&D efforts are needed to support future implementation of a sCO_2 cycle power plants utilizing a coal-fired heater.

Proposals are sought which will develop and validate models for heat transfer in coal-fired boilers for indirect SCO_2 applications that will provide the information and tools needed to design efficient and cost-effective combustors for indirect SCO_2. Wide variations in heat flux are inherent to PC-fired heaters. Maintaining tube temperatures within acceptable limits can be difficult in local regions, especially given the high inlet temperatures of the incoming CO_2 which are typical of sCO_2 power cycle applications. With further study and testing it might be possible to reduce the peak fluxes imposed on the tubes in various regions of the fired heater. This would offer the benefits of increased material choices, and might reduce the minimum pressure drop that is incurred on the CO_2 side.

Questions – Contact: Mark Freeman, Mark.Freeman@netl.doe.gov

d. Other

In addition to the specific subtopics listed, FE invites grant applications in other areas that fall within the scope of topic description provided above.

Questions – Contact: Mark Freeman, Mark.Freeman@netl.doe.gov

References: Subtopics a and b:

1. Next Generation Multi-Scale Modeling & Optimization Framework to Support the US Power Industry, Institute for the Design of Advanced Energy Systems, https://idaes.org/

2. Institute for the Design of Advanced Energy Systems, License, https://github.com/IDAES/idaes-pse/blob/master/LICENSE.md

References: Subtopic c:

1. Maxson, A., Miller, J., Buckmaster, D., et al, 2018, High-Efficiency Thermal Integration of Closed Supercritical CO2 Brayton Power Cycles with Oxy-Fired Heaters, Final Report, United States Department of Energy Office of Scientific and Technical Information, https://www.osti.gov/biblio/1469142-high-efficiency-thermal-integration-closed-supercritical-co2-brayton-power-cycles-oxy-fired-heaters-final-report

Return to Table of Contents

PROGRAM AREA OVERVIEW: OFFICE OF FUSION ENERGY SCIENCES

The mission of the Fusion Energy Sciences (FES) program is to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation needed to develop a fusion energy source. This is accomplished through the study of plasma, the fourth state of matter, and how it interacts with its surroundings. FES has four strategic goals:

- Advance the fundamental science of magnetically confined plasmas to develop the predictive capability needed for a sustainable fusion energy source;
- Support the development of the scientific understanding required to design and deploy the materials needed to support a burning plasma environment;
- Pursue scientific opportunities and grand challenges in high energy density plasma science to better understand our universe, and to enhance national security and economic competitiveness, and;
- Increase the fundamental understanding of basic plasma science, including both burning plasma and low temperature plasma science and engineering, to enhance economic competiveness and to create opportunities for a broader range of science-based applications.

The next frontier for fusion research is the study of the burning plasma state, in which the fusion process itself provides the dominant heat source for sustaining the plasma temperature (i.e., self-heating). Production of strongly self-heated fusion plasmas will allow the discovery and study of new scientific phenomena relevant to fusion energy, including the properties of materials in the presence of high heat and particle fluxes and neutron irradiation.

To achieve its research goals, FES invests in flexible U.S. experimental facilities of various scales, international partnerships leveraging U.S. expertise, large-scale numerical simulations based on experimentally validated theoretical models, development of advanced fusion-relevant materials, and invention of new measurement techniques.

FES also supports discovery plasma science, including research in laboratory plasma astrophysics, low-temperature plasmas, small-scale magnetized plasma experimental platforms, and high-energy-density laboratory plasmas.

Research supported by FES has led to many spinoff applications and enabling technologies with considerable economic and societal impact.

The following topics are restricted to advanced technologies and materials for fusion energy systems, fusion science, and technology relevant to magnetically confined plasmas.

For additional information regarding the Office of Fusion Energy Sciences priorities, click here.

26. FUSION MATERIALS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Fusion materials and structures must function for extended lifetimes in a uniquely hostile environment that includes a combination of high temperatures, high stresses, reactive chemicals, and intensely damaging radiation. The goal of this program is to establish the feasibility of designing, constructing and operating a fusion power plant with materials and components that meet demanding objectives for safety, performance, economics, and environmental impact.

Grant applications are sought in the following areas:

a. Development of Plasma Facing Component Materials

Solid plasma facing components (PFCs) are typically comprised of specialized plasma facing materials (typically tungsten or tungsten alloy) joined to either a water-cooled, copper-alloy heat sink or advanced, helium-cooled, refractory heat sink. In this area, research is sought to explore to following:

- Innovative tungsten based materials having good thermal conductivity, resistance to recrystallization and grain growth, improved mechanical properties (e.g., strength and ductility), and resistance to thermal fatigue
- Novel coatings or bulk specialized low-Z materials for improved plasma performance
- Innovative heat sink and component materials which enable enhanced cooling
- Innovative joining and fabrication methods for PFC manufacturing.

b. Development of Reduced Activation Ferritic Martensitic (RAFM) Steels Technologies

Such techniques could include but are not limited to appropriate welding, hot-isostatic pressing, hydroforming, and investment casting methods, as well as effective post joining heat treatment techniques and procedures, but a focus on joining and fabrication techniques. Appropriate fabrication technologies must produce components within dimensional tolerances, while meeting minimum requirements on mechanical and physical properties.

c. Development of Advanced Oxide Dispersion Strengthened (ODS) Ferritic Steels and Technologies

Approaches of interest include the development of low cost production techniques, improved isotropy of mechanical properties, development of joining and fabrication methods that maintain the properties of the ODS steel, and development of improved ODS steels with increased operating temperatures (up to ~800 ˚C).

d. Development of Functional Materials for Use in Fusion Reactors

Materials applications of high priority include both solid and liquid metal breeder designs, diagnostic systems, and liquid metal PFC systems, including lithium, tin, and gallium PFC concepts. Research is sought to explore: solid and liquid breeder materials; liquid metal materials compatibility issues; tritium control and processing materials (such as permeation barriers or permeable membrane materials); and window materials and hardened electronics for diagnostics.

Questions – Contact: Daniel Clark, daniel.clark@science.doe.gov

References:

1. Office of Fusion Energy Sciences, 2009, Research Needs for Magnetic Fusion Energy Sciences, Report of the Research Needs Workshop (ReNeW), U.S. Department of Energy, p. 412, https://www.osti.gov/biblio/972502-research-needs-magnetic-fusion-energy-sciences-report-research-needs-workshop-renew-bethesda-maryland-june

2. Fusion Energy Sciences Advisory Committee, 2012, Opportunities for Fusion Materials Science and Technology Research now and During the ITER Era, U.S. Department of Energy Office of Science, p. 141, http://science.energy.gov/~/media/fes/pdf/workshop-reports/20120309/FESAC-Materials-Science-final-report.pdf

3. Office of Fusion Energy Sciences, 2015, Fusion Energy Sciences Workshop on Plasma Materials Interactions: Report on Science Challenges and Research Opportunities in Plasma Materials Interactions, U.S. Department of Energy, p. 179, http://science.energy.gov/~/media/fes/pdf/workshop-reports/2016/PMI_fullreport_21Aug2015.pdf

27. SUPERCONDUCTING MAGNETS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

New or advanced superconducting magnet concepts are needed for plasma fusion confinement systems. Of particular interest are magnet components, superconducting, structural and insulating materials, or diagnostic systems that lead to magnetic confinement devices which operate at higher magnetic fields (14T-20T), in higher nuclear irradiation environments, provide improved access/maintenance or allow for wider operating ranges in temperature or pulsed magnetic fields.

Grant applications are sought for:

a. Superconducting Magnetic Technology

Innovative and advanced superconducting materials and manufacturing processes that have a high potential for improved conductor performance and low fabrication costs. Of specific interest are materials such as YBCO conductors that are easily adaptable to bundling into high current cables carrying 30-60 kA. Desirable characteristics include high critical currents at temperatures from 4.5 K to 50 K, magnetic fields in the range 5 T to 20 T, higher copper fractions, low transient losses, low sensitivity to strain degradation effects, high radiation resistance, and improved methods for cabling tape conductors taking into account twisting and other methods of transposition to ensure uniform current distribution.

Novel methods for joining coil sections for manufacture of demountable magnets that allow for highly reliable, re-makeable joints that exhibit excellent structural integrity, low electrical resistance, low ac losses, and high stability in high magnetic field and in pulsed applications. These include conventional lap and butt joints, as well as very high current plate-to-plate joints. Reliable sliding joints can be considered.

Innovative structural support methods and materials, and magnet cooling and quench protection methods suitable for operation in a fusion radiation environment that results in high overall current density magnets.

Novel, advanced sensors and instrumentation for monitoring magnet and helium parameters (e.g., pressure, temperature, voltage, mass flow, quench, etc.); of specific interest are fiber optic based devices and systems that allow for electromagnetic noise-immune interrogation of these parameters as well as positional information of the measured parameter within the coil winding pack. A specific use of fiber sensors is for rapid and redundant quench detection. Novel fiber optic sensors may also be used for precision measurement of distributed and local temperature or strain for diagnostic and scientific studies of conductor behavior and code calibration.

Radiation-resistant electrical insulators, e.g., wrap able inorganic insulators and low viscosity organic insulators that exhibit low gas generation under irradiation, less expensive resins and higher pot life; and insulation systems with high bond and higher strength and flexibility in shear.

Questions – Contact: Barry Sullivan, barry.sullivan@science.doe.gov

References:

1. Office of Fusion Energy Sciences, 2009, Research Needs for Magnetic Fusion Energy Sciences, Report of the Research Needs Workshop (ReNeW), U.S. Department of Energy, p. 285-292, http://science.energy.gov/~/media/fes/pdf/workshop-reports/Res_needs_mag_fusion_report_june_2009.pdf

2. Minervini, J.V. and Schultz, J.H., 2003, U.S. Fusion Program Requirements for Superconducting Magnet Research, IEEE Transactions on Applied Superconductivity, Vol. 13, Issue 2, p. 1524-1529, http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1211890

3. Bromberg, L., Tekula, M., El-Guebaly, L.A., et al, 2001, Options for the Use of High Temperature Superconductor in Tokamak Fusion Reactor Designs, Fusion Engineering and Design, Vol. 54, Issue 2, p. 167-180, https://www.sciencedirect.com/science/article/pii/S0920379600004324

4. Ekin, J.W., 2006, Experimental Techniques for Low-Temperature Measurements: Cryostat Design, Material Properties, and Superconductor Critical-Current Testing, Oxford University Press, Boulder, CO, p. 212, ISBN13: 978-0-19-857054-7, http://researchmeasurements.com/figures/ExpTechLTMeas_Apdx_English.pdf

28. INERTIAL FUSION ENERGY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

High-energy-density laboratory plasma (HEDLP) physics is the study of ionized matter at extremely high density and temperature, specifically when matter is heated and compressed to a point that the stored energy in the matter reaches approximately 100 billion Joules per cubic meter (the energy density of a hydrogen molecule). This corresponds to a pressure of approximately 1 million atmospheres or 1 Mbar. Research in HEDLP forms the scientific foundation for developing scenarios that could facilitate the transition from laboratory inertial confinement fusion (ICF) to inertial fusion energy (IFE). While substantial scientific and technical progress in inertial confinement fusion has been made during the past decade, many of the technologies required for an integrated inertial fusion energy system are still at an early stage of technological maturity. This relative immaturity ensures that commercially viable IFE remains a long-term objective. Research and development activities are sought which address specific technology needs (specified below), necessary to both assess and advance IFE.

a. Driver Technologies

Inertial fusion energy hinges on the ability to compress an ICF target in tens of nanoseconds and repeat this process tens of times per second. Thus, the development of technologies is needed to build a driver (e.g., lasers, heavy-ions, pulsed power) that can meet the IFE requirements for energy on target, efficiency, repetition rate, durability, and cost. Specific areas of interest include but are not limited to: wavelength and beam quality for lasers, brightness for lasers and heavy ions, and pulse shaping and power.

b. High-intensity Short-pulse Laser Technologies

Advances in HEDLP require access to ultrafast, high intensity lasers with powers typically > 100 TW. However, such high intensity lasers are presently limited to repetition rates of < 10 Hz. Technical solutions that will enable the generation of high energy (joule-level) laser pulses that can be focused to highly relativistic intensities at high repetition rate (100-1000 Hz). Important performance parameters include ultra-high contrast and good focusing ability.

In addition to the specific subtopics listed above, the Department invites grant applications in other areas of laser technologies that address the recommendations in the 2017 National Academy of Sciences report "Opportunities in Intense Ultrafast Lasers: Reaching for the Brightest Light."

Questions – Contact: Kramer Akli, Kramer.akli@science.doe.gov

References:

1. Fusion Energy Science Advisory Committee, 2009, Advancing the Science of High Energy Density Laboratory Plasmas, Report of the High Energy Density Laboratory Plasmas Panel of the Fusion Energy Sciences Advisory Committee, U.S. Department of Energy, p.184, http://science.energy.gov/~/media/fes/fesac/pdf/2009/Fesac_hed_lp_report.pdf

2. National Academies of Sciences, Engineering, and Medicine, 2018, Opportunities in Intense Ultrafast Lasers: Reaching for the Brightest Light Report, The National Academies Press, Washington, DC, p. 346, ISBN: 978-0-309-46769-8. http://nap.edu/24939

29. LOW TEMPERATURE PLASMAS AND MICROELECTRONICS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Low-temperature plasmas (LTPs) have continued to play major roles in breathtaking technological advances, ranging from the development of cost effective lighting to advanced microelectronics, that have improved the quality of our lives in many ways. LTPs are continuing to enable technological advances in new fields, such as destruction of antibiotic resistant bacteria and cancer therapy in plasma medicine. All of these advances are enabled by the unique properties of low-temperature, non-equilibrium plasmas and the chemistry they drive. Building upon fundamental plasma science, further developments are sought in plasma sources, plasma-surface interactions, and plasma control science that can enable new plasma technologies, marketable product, or impact in other areas or disciplines leading to even greater societal benefit. The focus of this topic is utilizing fundamental plasma science knowledge and turning it into new applications.

LTP science and engineering addresses research and development in partially ionized gases with electron temperatures typically below 10 eV. This is a field that accounts for an enormous range of practical applications, from light sources and lasers to surgery and making computer chips, among many others. The commercial and technical value of LTP is well established where much of this benefit has resulted from empirical development. As the technology becomes more complex and addresses new fields, such as advanced microelectronics and biotechnology, empiricism rapidly becomes inadequate to advance the state of the art. Predictive capability and improved understanding of the plasma state becomes crucial to address many of the intellectually exciting scientific challenges of this field.

All low-temperature plasma proposals must have a strong commercialization potential. Grant applications are sought in the following subtopics:

a. LTP Science and Engineering for Microelectronics and Nanotechnology
This subtopic is focused on improving our current understanding and scientific knowledge in the area of plasma-surface interactions and plasma assisted material synthesis related to advanced microelectronics and nanotechnology. Current challenges include: synthesis of new materials, nanomaterials, nanotubes, and complex materials, continuing miniaturization of integrated circuits, and advanced fabrication techniques for microelectronic devices, etc.

Questions – Contact: Nirmol Podder, Nirmol.Podder@science.doe.gov

b. LTP Science and Technology for Biomedicine
This subtopic is focused on improving our current understanding and scientific knowledge in the area of plasma-liquid and plasma-biomatter interactions related to plasma biomedicine. Current challenges include: development of microplasmas and plasma jet for biomedical applications such as wound healing and cancer therapy, effective inactivation of antibiotic resistant bacteria, understanding the mechanisms by which microorganisms and chemical compounds are inactivated in food sanitation, etc.

Questions – Contact: Nirmol Podder, Nirmol.Podder@science.doe.gov

c. Other Emerging LTP Technologies
In addition to the specific subtopics listed above, the Department invites grant applications in other emerging areas of plasma applications, including plasma catalysis involving plasma reactivity and catalyst selectivity, plasma assisted combustion involving improved efficiency of chemical processing, plasma separation technology, water purification technology, etc.

Questions – Contact: Nirmol Podder, Nirmol.Podder@science.doe.gov

References:

1. Basic Research Needs Workshop for Microelectronics, October 23-24, 2018, https://science.osti.gov/-/media/bes/pdf/reports/2018/Microelectronics_Brochure.pdf?la=en&hash=5FEFD0131FA3DA1CC8C3196452D1AFB5558DE720

2. U.S. Department of Energy Office of Fusion Energy Science, 2016, Plasmas at the Interface of Chemistry and Biology, Report on the Panel on Frontiers of Plasma Science, chapter 5, https://science.osti.gov/-/media/fes/pdf/program-news/Frontiers_of_Plasma_Science_Final_Report.pdf?la=en&hash=85B22EBF1CF773FFC969622524D603D755881999

3. U.S. Department of Energy Office of Fusion Energy Science, 2008, Low Temperature Plasma Science, Report of the Department of Energy, https://science.osti.gov/-/media/fes/pdf/workshop-reports/Low_temp_plasma_workshop_report_sept_08.pdf

4. National Research Council, 2007, Plasma Science: Advancing Knowledge in the National Interest, National Academies Press, Washington, D.C., https://www.nap.edu/catalog/11960/plasma-science-advancing-knowledge-in-the-national-interest

Return to Table of Contents

PROGRAM AREA OVERVIEW: OFFICE OF HIGH ENERGY PHYSICS

The goal of the Department of Energy's (DOE or the Department) Office of High Energy Physics (HEP) is to provide mankind with new insights into the fundamental nature of energy and matter and the forces that control them. This program is a major component of the Department's basic research mission. Such foundational research enables the nation to advance its scientific knowledge and technological capabilities, to advance its industrial competitiveness, and to discover new and innovative approaches to its energy future.

The DOE HEP program supports research in three discovery frontiers, namely, the energy frontier, the intensity frontier, and the cosmic frontier. Experimental research in HEP is largely performed by university and national laboratory scientists, using particle accelerators as well as telescopes and underground detectors located at major facilities in the U.S. and abroad. Under the HEP program, the Department operates the Fermi National Accelerator Laboratory (Fermilab) near Chicago, IL. The Department also has a significant role in the Large Hadron Collider (LHC) at the CERN laboratory in Switzerland. The Fermilab complex includes the Main Injector (which formerly fed the now dormant Tevatron ring), which is used to create high-energy particle beams for physics experiments, including the world's most intense neutrino beam. The Main Injector is undergoing upgrades to support the operation of Fermilab's present and planned suite of neutrino and muon experiments at the intensity frontier. Another Fermilab upgrade project called PIP-II (Proton Improvement Plan II) will greatly increase the intensity of proton beams sent to the Main Injector. The SLAC National Accelerator Laboratory and the Lawrence Berkeley National Laboratory are involved in the design of state-of-the-art accelerators and related facilities for use in high-energy physics, condensed matter research, and related fields. SLAC facilities include the three kilometer long Stanford Linear Accelerator capable of generating high energy, high intensity electron and positron beams. The first two kilometers of the linear accelerator are used for the Facility for Advanced Accelerator Experimental Tests (FACET), now undergoing an upgrade called FACET-II. At Argonne National Laboratory resides the Argonne Wakefield Accelerator (AWA) facility, which houses two test electron accelerators, one for 15 MeV electrons, and the other for 70 MeV electrons. Experiments focus on two-beam and collinear wakefield acceleration as well as tests of novel accelerator structures and beam-line components. Brookhaven National Laboratory operates the Accelerator Test Facility, which supports accelerator science and technology demonstrations with electron and laser beams. While much progress has been made during the past five decades in our understanding of particle physics, future progress depends on the availability of new state-of-the-art technology for accelerators and detectors.

As stewards of accelerator technology for the nation, HEP also supports development of new concepts and capabilities that further scientific and commercial needs beyond the discovery science mission. Quantum information science is another rapidly-developing area that both benefits from expertise in the HEP community and offers novel approaches for extending HEP science. The DOE SBIR program provides a focused opportunity and mechanism for small businesses to contribute new ideas and new technologies to the pool of knowledge and technical capabilities required for continued progress in HEP research, and to turn these novel ideas and technologies into new business ventures.

Grant applications must be informed by the state of the art in High Energy Physics applications, commercially available products, and emerging technologies. A proposal based on merely incremental improvements or little innovation will be considered non-responsive unless context is supplied that convincingly shows its potential for significant impact or value to the DOE High Energy Physics program. DOE also expects all applicants to address commercialization opportunities for their product or service in adjacent markets such as medicine, homeland security, the environment and industry.

For additional information regarding the Office of High Energy Physics priorities, click here.

30. ADVANCED CONCEPTS AND TECHNOLOGY FOR PARTICLE ACCELERATORS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The DOE HEP program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. The strategic plan for HEP includes initiatives on the energy and intensity frontiers, relying on accelerators capable of delivering beams of the required energy and intensity. As high energy physics facilities get bigger and more costly, the DOE HEP program seeks to develop advanced technologies that can be used to reduce the overall machine size and cost, and also to develop new concepts and capabilities that further scientific and commercial needs beyond HEP's discovery science mission.

In many cases the technology sought is closely tied to a specific machine concept which sets the specifications (and tolerances) for the technology. Applicants are strongly encouraged to review the references provided. Applications to subtopics specifically associated with a machine concept that do not closely adhere to the specifications of the machine will be considered non- responsive. For subtopics that are not machine-specific, applicants are strongly advised to understand the state-of- the-art and to clearly describe in the application what quantitative advances in the technology will result.

Grant applications are sought only in the following subtopics:

a. Permanent Magnetic Optics at Cryogenic Temperatures

Cryogenic normal and superconducting accelerators can produce significant advantages for the production of high average power beams with high efficiency. However, the inclusion of a cryogenic vessel limits the possible options for positioning of magnetic optics. Developing magnetic optics--in particular permanent magnet quadrupoles--would provide significant in beamline design for future accelerators. Permanent magnets that operate cryogenic temperatures also offer the possibility of increased performance in terms of strength with appropriate design and understanding of material properties. The development of this technology would be widely applicable to many fields investigating material properties at low temperatures in strong magnetic fields provided for a large potential market. This topic does not include superconducting technology.

Questions – Contact: John Boger, john.boger@science.doe.gov

b. High Strength, High Conductivity Alloys for Particle Accelerators

The feasibility and implementation of next-generation particle accelerators is dependent upon their cost and performance metrics, which scale with accelerating gradients. High strength materials have been determined to enable higher accelerating gradients than what can be achieved with conventionally employed materials. Commercially available high strength materials are often not suitable for operation in accelerator systems. Precipitation and solution hardened alloys can recrystallize and lose their strength during the assembly (high temperature brazing) and processing (bake-out) stages, while dispersion strengthened alloys induce early onset of breakdown due to their content of dielectric particles. Development and manufacture of high strength (Sy>300 MPa) high conductivity (>95%IACS) alloys that maintain their properties at temperatures up to 500C and that are suitable for operation in ultra-high vacuum (<1E-9 Torr) environments would enable higher performance and more compact accelerators (as well as RF sources). Proposals submitted to this topic should be directed towards the production of a string of resonant cavities (for accelerator or RF source) manufactured out of a new high strength high conductivity alloy suitable for ultra-high vacuum operation environments. Proposals towards development of alternative techniques for assembly and processing of commercially available high strength alloys into a string of resonant cavities while maintaining their strength into the stages of accelerator or RF source operation without causing breakdown will also be considered.

Questions – Contact: John Boger, john.boger@science.doe.gov

c. Novel High-Gradient Microwave Accelerating Structures

Proposals are sought to develop novel microwave accelerating structures with high-gradient (>0.5 GV/m), and/or high-efficiency (RF to beam efficiency >40%) based on emerging technologies, such as cold metallic materials, cold dielectric materials, metallic/dielectric hybrid, and novel joining/fabrication.

Questions – Contact: John Boger, john.boger@science.doe.gov

d. Space Charge Modeling in High Intensity Hadron Beams

As accelerators push to higher average power, the limit of 1 W/m losses becomes a tighter constraint on the fraction of beam that can be lost. Designing these accelerators requires higher fidelity modeling to accurately predict beam loss due to collective effects, specifically space charge driven beam loss. Some promising recent avenues are symplectic space charge algorithms [1], and the fast multipole method [2]. Grant applications are sought for novel algorithms that can accurately model space charge in high intensity hadron beams, including boundary conditions at the beam pipe. Proposals must address the issue of scaling to many cores for simulations in HPC environments.

Questions – Contact: John Boger, john.boger@science.doe.gov

e. Computation and Simulation of Residual Gamma Dosage in Accelerator Enclosures

Grant applications are sought to develop a tool for expedited and accurate simulation of 3D maps of residual gamma dose rates in accelerator enclosures, and on and around the machine components, needed for Advanced Accelerator Computer Modeling for the Intensity Frontier applications. This would allow one to develop a work plan in the accelerator tunnel and minimize hands-on maintenance and installation time, as well as to minimize the time and the dose received by Radiation Workers, while in the tunnel. The tool should be based on existing and widely used Monte Carlo codes used in accelerator applications. A user-friendly CAD-to-Monte Carlo interface to automate building realistic 3D geometries of the accelerator equipment and tunnel in order to calculate residual dosage would be of great value.

Questions – Contact: John Boger, john.boger@science.doe.gov

f. Accelerator Simulation Workflow Optimization

Accelerator cavities operating at high gradients are subject to radiation damage from high energy electrons hitting the surface of the cavity wall [3]. Electrons from field emission on a cavity surface can produce dark current, and they can interact with the material in the cavity wall to produce unwanted radiation that can affect the performance and operation of the accelerator. A modeling tool for simulating particle electrodynamics and particle-matter interaction together is needed to evaluate radiation effects. The parallel finite-element electromagnetics code suite ACE3P can model dark current propagation in the vacuum region of an accelerator system and then couple to a particle-matter interaction code [4, 5] for radiation calculation in the cavity enclosure. The present approach is cumbersome and error-prone, requiring high-fidelity transfer of geometry and particle data at the cavity wall interface, often involving more than a single researcher to accomplish the simulation, and using different visualization tools for the respective codes. The integration of ACE3P and particle-matter interaction codes such as Geant4 into a single simulation workflow from start to end will circumvent these problems and significantly facilitate studies of machine protection and instrument functionalities during accelerator operation, without the need for individual researchers performing different tasks and communicating with each other in order to carry out simulations for different stages in the workflow.

Questions – Contact: John Boger, john.boger@science.doe.gov

g. Accelerator Machine Learning and Controls

Machine learning (ML) is a promising tool for future accelerator operations [6], although the technology is still immature. With regard to accelerator operations, there is a particular need to optimize and modernize existing control systems.

Experimental demonstration that machine learning techniques, including diagnostic tools amenable to machine learning, could be used to predict or detect undesirable beam dynamics or directly control the accelerator to tune away from these undesirable operating points, are a critical paths to integrating machine learning techniques into accelerator operations.

Proposals are sought for the development of machine learning techniques that are broadly applicable to a wide range of machines. Successful proposals, however, must include plans for experimental demonstration and validation that any proposed ML techniques, including compatible diagnostic tools, could be used to predict or detect undesirable beam dynamics or directly control the accelerator to tune away from these undesirable elements.

Proposals are sought for either of the following:

(a) Novel control schemes for high-intensity rapid cycling synchrotrons are required in order to optimize injection, capture, and acceleration. Grant applications are sought to develop innovative graphical user interfaces that facilitate the design of new or improved control algorithms through effective combination of beam diagnostics, online models, integrated high-fidelity off-line simulation codes, and machine learning techniques. Effective use of existing facilities for testing and proof-of-principle experiments is encouraged.

(b) Proposals are sought to develop low-cost, non-interceptive diagnostics (e.g. charge, position, bunch length with large dynamic range such as operating charge range of 1pC to 100 nC. The extracted beam information along the beamline should be able to allow rapid beamline tuning for the desired performance or improvement of performance.

Questions – Contact: John Boger, john.boger@science.doe.gov

h. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: John Boger, john.boger@science.doe.gov

Return to Table of Contents

References:

1. Qiang, J., 2017, Symplectic multiparticle tracking model for self-consistent space charge simulation, Physical Review Accelerators and Beams vol. 20, 014203, https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.20.014203

2. Zhang, H., Berz, M., 2011, The fast multipole method in the differential algebra framework, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, vol. 645, 1, p. 338-344, https://www.sciencedirect.com/science/article/pii/S0168900211001318?via%3Dihub

3. Marhauser, F., Johnson, R., Rodriguez, J., et al, 2013Field Emission and Consequences as Observed and Simulated for CEBAF Upgrade Cryomodules, Proceedings of SRF2013, Paris, France, September 23-27, 2013, http://accelconf.web.cern.ch/AccelConf/SRF2013/papers/tup095.pdf

4. Santana Leitner, M., Ge, L., Li, Z, et al, 2016, Studies of radiation fields of LCLS-II super conducting radio frequency cavities, International Journal of Modern Physics: Conference Series, vol. 44 1660209, https://www.worldscientific.com/doi/abs/10.1142/S201019451660209X

5. Li, Y., Liu, K., Geng, R., et al, 2013, Research on Field Emission and Dark Current in ILC Cavities, Proceedings of SRF, Paris, France, September 23 - 27 2013, http://accelconf.web.cern.ch/AccelConf/SRF2013/papers/tuioa06.pdf

6. Edelen, A.L., Biedron, S.G., Chase, B.E., et al, 2016, Neural Networks for Modeling and Control of Particle Accelerators, IEEE Transactions on Nuclear Science, vol. 63, 2, https://ieeexplore.ieee.org/document/7454846

7. Edelen, A., Adelmann, A., Neveu, N., et al, Machine Learning to Enable Orders of Magnitude Speedup in Multi-Objective Optimization of Particle Accelerator Systems, arXiv:1903.07759, https://www.researchgate.net/publication/331888440_Machine_Learning_to_Enable_Orders_of_Magnitude_Speedup_in_Mult-Objective_Optimization_of_Particle_Accelerator_Systems

31. RADIO FREQUENCY ACCELERATOR TECHNOLOGY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Radio frequency (RF) technology is a key technology common to all high energy accelerators. RF sources with improved efficiency and accelerating structures with increased accelerating gradient are important for keeping the cost down for future machines. DOE-HEP seeks advances directly relevant to HEP applications, and also new concepts and capabilities that further scientific and commercial needs beyond HEP's discovery science mission.

In many cases the technology sought is closely tied to a specific machine concept which sets the specifications (and tolerances) for the technology. Applicants are strongly encouraged to review the references provided. Applications to subtopics specifically associated with a machine concept that do not closely adhere to the specifications of the machine will be considered non- responsive.

Return to Table of Contents

For subtopics that are not machine-specific, applicants are strongly advised to understand the state-of- the-art and to clearly describe in the application what quantitative advances in the technology will result.

a. Low Cost Radio Frequency Power Sources for Accelerator Application

Low cost, highly efficient RF power sources are needed to power accelerators. Achieving power efficiencies of 70% or better, decreasing costs below $2/peak-Watt for short-pulse sources, and below $3/average-Watt for CW sources are essential. Sources must phase lock stably (<1 degree RMS phase noise) to an external reference, and have excellent output power stability (<1% RMS output power variation). Device lifetime must exceed 10,000 operating hours. Priority will be given to applications that develop RF power sources operating at frequencies that are in widespread use at the large Office of Science accelerators. Sources may be either vacuum tube or solid state, however: (1) if the proposed source is a vacuum tube, priority will be given to applications for tubes with operating voltages <100kV, and (2) if the proposed source is a solid-state power amplifier, strong evidence and arguments must be presented as to how the R&D will enable the cost metric above to be met.

For normal conducting accelerators, microsecond-pulsed high-peak-power sources are needed that operate at L-band or higher frequencies. The peak output power of individual sources is flexible, but must be compatible with delivering ~100 MW/meter to compact accelerators. The source must support >0.1% duty factor operation.

For superconducting accelerators, both millisecond-pulsed and CW sources are needed that operate at L-band frequencies. The peak output power of individual sources is flexible, but must be compatible with delivering ~100 kW/meter to high power accelerators. If the source is not CW capable, it must support >5.0% duty factor operation.

Applications must clearly articulate how the proposed technology will meet all metrics listed in this section.

Questions – Contact: Eric Colby, Eric.Colby@science.doe.gov

b. High Efficiency High Average Power RF Sources

Future high power accelerators will require highly efficient sources of megawatt-class radiofrequency power. R&D to significantly improve the power efficiency of high-average-power (CW or high duty factor) radiofrequency tubes is sought. Net tube power efficiency (including focusing magnet power) must exceed 80%, and average tube power must exceed 250 kW, with a pulse format (peak power, pulse length) that is appropriate for either normal conducting or superconducting accelerators, and an output that is stably phase locked to an external reference. The proposed device must provide an economical route to producing 1 MW or more of average power by scaling, coherent combination, or both. For cost efficiency, priority will be given to applications to develop RF power sources that may be tested at a national accelerator facility. Non-DOE locations that could support high power radiofrequency tube testing include: Naval Research Laboratory, NSWC Dahlgren, and smaller university test facilities such as those at UCLA, MIT, and TAMU.

Questions – Contact: Eric Colby, Eric.Colby@science.doe.gov

c. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Eric Colby, Eric.Colby@science.doe.gov

References

1. Hartill, D., 2015, Accelerating Discovery: A Strategic Plan for Accelerator R&D in the U.S., https://science.osti.gov/-/media/hep/hepap/pdf/Reports/Accelerator_RD_Subpanel_Report.pdf (see especially section 7)

2. Henderson, S., Waite, T., 2015, Workshop on Energy and Environmental Applications of Accelerators, see especially section 2.11, http://science.osti.gov/~/media/hep/pdf/accelerator-rd-stewardship/Energy_Environment_Report_Final.pdf

32. LASER TECHNOLOGY R&D FOR ACCELERATORS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Lasers are used or proposed for use in many areas of accelerator applications: as drivers for novel accelerator concepts for future colliders; in the generation, manipulation, and x-ray seeding of electron beams; in the generation of electromagnetic radiation ranging from THz to gamma rays; and in the generation of neutron, proton, and light ion beams. In many cases ultrafast lasers with pulse lengths well below a picosecond are required, with excellent stability, reliability, and beam quality. With applications demanding ever higher fluxes of particles and radiation, the driving laser technology must also increase in repetition rate—and hence average power—to meet the demand. Please note that proposals submitted in this topic should clearly articulate the relevance of the proposed R&D to HEP's mission.

This topic area is aimed at developing technologies for ultrafast lasers capable of high average power (kilowatt-class) operating at the high electrical-to-optical efficiency (>20%) needed for advanced accelerator applications.

Accelerator applications of ultrafast lasers call for one of the following four basic specifications:

	Type I	Type II	Type III	Type IV
Wavelength (micron)	1.5-2.0	0.8-2.0	2.0-5.0	2.0-10.0
Pulse Energy	3 microJ	3 J	0.03–1 J	300 J
Pulse Length	300 fs	30–100 fs	50 fs	100–500 fs
Repetition Rate	1–1300 MHz	1 kHz	1 MHz	100 Hz
Average Power	Up to 3 kW	3 kW	3 kW and up	30 kW
Energy Stability	<1 %	<0.1%	<1%	<1%
Beam Quality	M^2<1.1	Strehl>0.95	M^2<1.1	M^2<1.1
Wall-plug Efficiency	>30%	>20%	>20%	>20%
Pre-Pulse Contrast	N/A	$>10^{-9}$	N/A	$>10^{-9}$
CEP-capable	Required	N/A	Required	N/A
Optical Phase Noise	<5°	N/A	<5°	N/A

Wavelength Tunability Range	0.1%	0.1%	10%	0.1%

Grant applications are sought to develop lasers and laser technologies for accelerator applications only in the following specific areas:

a. Ceramic-Based Optical Materials

To achieve high average power and high peak power will require new gain materials with superior damage threshold, dopant density, optical bandwidth, and thermal properties. Sintered laser gain materials for ultrafast lasers offer promise of achieving many of these characteristics. Candidate materials must achieve broad bandwidth (>10%), high peak power (>10 TW), and endure sustained high average power (>kW) operation. Proposals to develop new laser gain materials and/or advanced sintering techniques for producing very high quality laser gain media with large apertures (e.g. greater than 4 cm dia) are sought. Proposals to develop techniques capable of producing precisely controlled spatial gain profiles are strongly encouraged.

The successful proposal will include optical characterization of finished ceramic samples to demonstrate the optical qualities of the sample, including measurements of spectral absorption, transparency (scattering), and accuracy of the doping profile. A demonstration of lasing of the sample ceramic material (over a small aperture) is highly preferred. Sesquioxide ceramics are preferred, but other materials (e.g., polycrystalline sapphire) will be considered.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

b. Aperture-Scalable High Performance Diffraction Gratings

Diffraction gratings are employed in high energy laser systems in several ways, including pump wavelength stabilization, spectral beam combining, pulse compression, and near-field spatial filtering. These components are of critical importance in enabling high average power petawatt-class laser systems.

Traditional surface-etched gratings, while aperture scalable, suffer from poor diffraction efficiency and high loss. Volumetric gratings deliver high diffraction efficiencies with excellent spectral and angular selectivity, but suffer from poor uniformity when scaling to large apertures needed in high energy laser systems.

Grant proposals are sought which will enable scaling of dispersive optical elements to large apertures (greater than 10 cm x 10 cm) while maintaining excellent uniformity (<quarter wave of distortion over the active aperture), good bandwidth performance (>5% minimum, with >10% preferred), high diffraction efficiency (>95% minimum at 1 micron or >90% minimum at 10 microns), and high optical damage threshold (>0.5 J/cm2 at 1 ps or >10 J/cm2 at 1 ns). Proposals that include work to develop new grating substrate technologies (e.g., ceramics with or without embedded cooling) that are capable of very high average power operation (>1 kW average) are encouraged. Of particular interest are technologies which enable such improvements while reducing the cost of such components.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

c. End-to-End Systems Modeling of Large Ultrafast Laser Systems

Development and engineering of complex state-of-the-art femtosecond laser systems requires sophisticated computational design tools and predictive models. Fully integrated 4D modeling tools are needed to design and use high power laser systems for accelerator applications. An example would be calculating the pump distribution and amplified spontaneous emission (ASE) in an amplifier, calculating the effective gain distribution in the amplifier, calculating and accounting for heat loading and flow, and using the resulting gain and refractive index distributions to conduct an integrated propagation simulation for a chain of amplifiers.

Grant proposals are sought for the development of computational tools that support end-to-end design of laser systems, to include accurate modeling of pump light absorption and spatio-temporal gain modeling; calculation of ASE in unseeded and seeded amplifier chains; accurate modeling of the propagation and amplification of the seed pulse, including higher-order effects such as gain narrowing, thermal lensing, pump depletion, B-integral effects, and dispersion. While a general code capable of modeling either fiber laser systems or free-space laser systems is desired, a highly optimized solution addressing just one architecture type is also of interest.

Optional but highly desirable features include: sophisticated parametric system optimization, estimation of carrier envelope phase distortions, modeling trains of phase- and spectrally-encoded pulses, and the ability to support Raman and Brillouin scattering effects (esp. for fiber systems) in a future code release.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

d. Large Format Faraday Isolators for High Power Ultrafast Laser Systems

The development of kilowatt-class ultrafast laser systems will necessitate the development of large-aperture low-loss Faraday isolators capable of handling high repetition rate use with high peak power ultrafast laser systems. Optical components must operate reliably with a continuous pulse train of Joule-class, sub-picosecond length laser pulses at either Yb, Tm, or CO2 wavelengths. Optical components must preserve very high beam quality (M-squared<1.2) and operation must be thermomechanically stable (i.e. minimal beam steering, minimal thermal lensing, and minimal degradation of the basic function of the device) over the entire average power range from 0 to 100%.

Proposals are sought to develop a large-aperture low-loss Faraday isolator capable of handling either:

- 1 kW of continuous input power centered at either Yb or Tm wavelengths, with a pulse format of 1 kHz, 1 Joule, 100 fsec pulses; transmission must exceed 95% and isolation must exceed 30 dB across the entire 5% bandwidth; a credible technical path to extend the design to 100 kW average power must be outlined in the proposal;

Or

- 100 W of continuous input power centered at CO2 wavelengths (9.2 microns preferred), with a pulse format of 5 Hz, 20 Joule, 300 fsec pulses; transmission must exceed 90% and isolation must exceed 30 db across the entire 10% bandwidth; a credible technical path to extend the design to 1 kW average power must be outlined in the proposal.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

References:

1. Office of Science, 2013, Workshop on Laser Technology for Accelerators: Summary Report, U.S. Department of Energy, p. 47. https://projects-web.engr.colostate.edu/accelerator/reports/Lasers_for_Accelerators_Report_Final.pdf

2. Hogan, M.J., 2016, Advanced Accelerator Concepts 2014: 16th Advanced Accelerator Concepts Workshop, AIP Conference Proceedings, San Jose, C.A., Vol. 1777, 010001, ISBN: 978-0-7354-1439-6. https://aip.scitation.org/toc/apc/1777/1?expanded=1777

33. SUPERCONDUCTOR TECHNOLOGIES FOR PARTICLE ACCELERATORS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Superconducting materials are widely used in particle accelerators to create large continuous electric and magnetic fields for beam acceleration and manipulation. Advanced R&D is needed in support of this research in high-field superconductor, superconducting magnet, and superconducting RF technologies. This topic addresses only those superconducting magnet development technologies that support accelerators, storage rings, and charged particle beam transport systems, only those superconducting wire technologies that support long strand lengths suitable for winding magnets without splices, and only those superconducting RF technologies that advance high gradient, high quality factor cavities for accelerator applications.
For referral to lab and university scientists in your area of interest contact: Ken Marken, ken.marken@science.doe.gov.

Grant applications are sought only in the following subtopics:

a. High-Field Superconducting Wire and Cable Technologies for Magnets
Grant applications are sought to develop improved superconducting wire for high field magnets that operate at 16 Tesla (T) field and higher. Proposals should address production scale (> 3 km continuous lengths) wire technologies at 16 to 25 T and demonstration scale (>1 km lengths) wire technologies at 25 to 50 T. Current densities should be at least 400 amperes per square millimeter of strand cross-section (often called the engineering current density) at the target field of operation and 4.2 K temperature. Tooling and handling requirements restrict wire cross-sectional area to the range 0.4 to 2.0 square millimeters, with transverse dimension not less than 0.25 mm. Vacuum requirements in accelerators and storage rings favor operating temperatures below 20 K, so high-temperature superconducting wire technologies will be evaluated only in this temperature range. Of specific interest are the HTS materials $Bi_2Sr_2CaCu_2O_8$ (Bi-2212) and (RE) Ba2Cu3O7 (ReBCO) that are engineered for high field magnet applications. Also of interest are innovative processing methods and/or starting materials that significantly improve performance and lower the cost of Nb_3Sn magnet conductor. All grant applications must result in wire technology that will be acceptable for accelerator magnets, including not only the operating conditions mentioned above, but also production of a sufficient amount of material (1 km minimum continuous length) for winding and testing cables and subscale coils.

New or improved wire technologies must demonstrate at least one of the following criteria *in comparison to present art*:

1) property improvement, such as higher current density or higher operating field;
2) improved tolerance to property degradation as a function of applied strain;
3) reduced transverse dimensions of the superconducting filaments (sometimes called the effective filament diameter), in particular to less than 30 micrometers at 1 mm wire diameter, with minimal concurrent reduction of the thermal conductivity of the stabilizer or strand critical current density;
4) innovative geometry for ReBCO materials that leads to lower magnet inductance (cables) and lower losses under changing transverse magnetic fields;
5) correction of specific processing flaws (not general improvements in processing), to achieve properties in wires of more than 1 km length that are presently restricted to wire lengths of 100 m or less;
6) significant cost reduction for equal performance in all regards, especially current density and length.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

b. Superconducting Magnet Technology

Grant applications are sought to develop:

1) very high field (greater than 16 T) HTS/LTS hybrid dipole magnets;
2) designs and prototypes for HTS/LTS hybrid solenoid systems capable of achieving 30 to 40T axial fields and warm bores with a diameter ≥2 cm;
3) fast cycling HTS magnets capable of operation at or above 4T/s;
4) improved HTS magnet protection systems that incorporate innovative detection methods for faster and more reliable quench detection, which may include quench antennas, stray capacitance, or acoustic techniques;
5) liquid-helium-operating electronics for superconducting magnets to enable higher speed and lower noise diagnostic data transfer.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

c. Superconducting RF Cavities and Component

Superconducting RF cavities continue to be a key technology for future HEP machines**.** Grant applications are sought in the following technology areas.

1) New SRF cavity designs for operation with high current beams. The cavity should provide efficient high-order mode extraction while not sacrificing good SRF performance. The goal of the new designs is to achieve higher-order mode loaded quality factors in the 10^2 – 10^3 range for circular accelerators and 10^3 – 10^4 range for linacs.
2) Improved SRF low-beta cavity designs which mitigate multipactoring (MP), field emission (FE) and reduced losses.
3) New cost-efficient and improved reliability designs of high-power input couplers in the frequency range of 325 MHz to 1.3 GHz.
4) Non-ferrite circulators are needed for measuring the new generation of very high Q superconducting cavities. Accuracy and stability of these measuring and isolating devices are the main limitations on test accuracy. Eliminating ferrite from the circulator reduces the power-dependence of the match and directivity of these devices. This could be very useful for making low-power Q_0 measurements of near-critically coupled cavities in vertical test. Also, if higher power devices can be developed that are cost

competitive with existing designs but offer improved accuracy, they would find wide applicability in operating accelerators.

5) SRF cryomodule diagnostics that aid in preserving the high performance achieved by SRF cavities during vertical tests throughout the SRF cryomodule assembly, commissioning and operation.
6) New types of compact, inexpensive, field-deployable, stand-alone, turn-key SRF cryomodules which are portable, robust and with small static losses with improved properties (static and dynamic thermal loads, vibration and structural integrity) and operated at or above 4.2 K, e.g. based on Nb_3Sn coating.
7) Conduction cooling techniques for multi-cell cavities including novel thermal connections to single or multiple cryocoolers that accommodate 10 W static and dynamic losses from a high-Q_0 cavity such as a 4.5-cell 650 MHz cavity or a 9-cell cavity at 1.3 GHz. The design should be robust and able to withstand vertical and horizontal orientation of the accelerator with temperature difference of < 1 K between the cryocooler and a cavity operating between 4.2 K – 5 K.

d. Ancillary Technologies for Superconducting Magnets

Grant applications are sought for development of either new types of resins or modifiers or additives to existing baseline epoxy resins (e.g. CTD-101K) used in wet winding or impregnation of superconducting magnets, to provide improved properties, including but not limited to higher toughness, higher specific heat and/or higher thermal conductivity. New resin systems with potential to reduce quench training in Nb-Ti and Nb_3Sn accelerator magnets are particularly of interest. A qualified impregnation epoxy must meet several criteria:

1) The capability to fully impregnate a large magnet without leaving voids. This is usually associated with low viscosity, long pot life and wetting of the surfaces of other components (metal and fiber glass insulation).
2) Mechanical strength. The epoxy must be able to withstand high mechanical loads at both room temperature and cryogenic temperatures, mostly in a combination of compression and shear loads. The epoxy should have a low risk of cracking at cryogenic temperatures.
3) Chemical compatibility with other components in the magnet.
4) Radiation resistance. This is required for magnets that are exposed to radiation, such as those used in the interaction regions of high energy particle colliders and pion capture solenoids.
5) Dielectric strength.

Grant applications are sought for thin and reliable electrical insulation and coil fabrication technology for high-temperature superconducting REBCO and Bi-2212 magnets for achieving a high overall current density.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

References: Subtopics a and b:

1. Larbalestier, D., Jiang, J., Trociewitz, U.P., et al, 2014, Isotropic round-wire multifilament cuprate superconductor for generation of magnetic fields above 30 T, Nature Materials, vol.13, p. 375 https://www.nature.com/articles/nmat3887

2. Maeda, H., Yanagisawa, Y., 2014, Recent Developments in High-Temperature Superconducting Magnet Technology (Review), IEEE Transactions on Applied Superconductivity, vol. 24, no. 3, 4602412 https://ieeexplore.ieee.org/document/6649987

3. Todesco, E., Bottura, L., Rijk, G., et al, 2014, Dipoles for High-Energy LHC", IEEE Transactions on Applied Superconductivity, vol. 24, no. 3, 4004306 https://ieeexplore.ieee.org/document/6656892

4. Advances in Cryogenic Engineering – Materials: Proceedings of the International Cryogenic Materials Conference (ICMC) 2017 2017 IOP Conference Series: Materials Science and Engineering 279 011001, https://iopscience.iop.org/article/10.1088/1757-899X/279/1/011001

5. Advances in Cryogenic Engineering: Proceedings of the Cryogenic Engineering Conference (CEC) 2017, 2017 IOP Conf. Ser.: Mater. Sci. Eng. 278 011001 https://iopscience.iop.org/article/10.1088/1757-899X/278/1/011001

6. Scanlan, R., Malozemoff, A.P., Larbalestier, D.C., 2004, Superconducting Materials for Large Scale Applications, Proceedings of the IEEE, vol. 92, issue 10, pp. 1639-1654, http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=1335554&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F5%2F29467%2F01335554

7. Proceedings of the 2018 Applied Superconductivity Conference, IEEE Transactions on Applied Superconductivity, vol. 29 no. 5 https://ieeexplore-ieee-org.proxy.scejournals.org/document/8745702

8. The Twenty-fifth International Conference on Magnet Technology, IEEE Transactions on Applied Superconductivity. vol. 28, no. 3 https://ieeexplore-ieee-org.proxy.scejournals.org/xpl/tocresult.jsp?isnumber=8114526&punumber=77

9. Ogitsu, T., Devred, A., Kim, K., et al, 1994, Quench Antenna for Superconducting Particle Accelerator Magnets, IEEE Transactions on Magnetics, vol. 30, 2273, https://ieeexplore.ieee.org/document/305728

10. Iwasa, Y., 1992, Mechanical Disturbances in Superconducting Magnets-A Review, IEEE Transactions on Magnetics, vol. 28 113, https://ieeexplore.ieee.org/document/119824

References: Subtopic c:

1. Gurevich, A., 2012, Superconductivity Radio-Frequency Fundamentals for Particle Accelerators, Reviews of Accelerator Science and Technology, 5, 119-146, https://www.worldscientific.com/doi/abs/10.1142/S1793626812300058

2. Grassellino, A., Romanenko, A., Trenikhina, Y., et al., 2013, Nitrogen and argon doping of niobium for superconducting radio frequency cavities: a pathway to highly efficient accelerating structures, Superconductor Science and Technology, https://www.researchgate.net/publication/237000318_Nitrogen_and_argon_doping_of_niobium_for_superconducting_radio_frequency_cavities_A_pathway_to_highly_efficient_accelerating_structures

3. Geng, R.L., Barnes, P., Hartill, H., et al, 2003, First RF Test at 4.2 K of a 200 MHz Superconducting Nb-Cu Cavity, Proceedings of the 2003 Particle Accelerator Conference (PAC2003), vol. 2, pp. 1309-1311, https://www.classe.cornell.edu/public/SRF/2003/SRF030520-13/SRF030520_13.pdf

4. Singer, W., 2006, Seamless/bonded niobium cavities. Physica C: Superconductivity, Proceedings of the 12th International Workshop on RF Superconductivity, vol. 441, issues 1-2, pp. 89-94, http://www.sciencedirect.com/science/article/pii/S0921453406001584

5. Bousson, S., Fouaidy, M., Junquera, T., et al, 1999, An Alternative Scheme for Stiffing SRF Cavities by Plasma Spraying, Proceedings of the 1999 Particle Accelerator Conference, vol. 2, p. 919-921, https://www.researchgate.net/publication/3816133_An_alternative_scheme_for_stiffening_SRF_cavities_by_plasma_spraying

6. Dzyuba, A., Romanenko, A., Cooley, L.D., 2010, Model for Initiation of Quality Factor Degradation at High Accelerating Fields in Superconducting Radio-frequency Cavities, Superconductor Science and Technology, vol. 23, issue 12, article ID: 125011, https://www.researchgate.net/publication/45929379_Model_for_initiation_of_quality_factor_degradation_at_high_accelerating_fields_in_superconducting_radio-frequency_cavities

7. Dey, J., Kourbanis, I., A New Main Injector Radio Frequency System For 2.3 MW Project X Operations, Proceedings of 2011 Particle Accelerator Conference, New York, NY, https://accelconf.web.cern.ch/accelconf/PAC2011/papers/tup131.pdf

8. Yao, Z., Laxdal, R.E., Zvyagintsev, V., 2015, Balloon Variant of Single Spoke Resonator, Proceedings of SRF2015, Whistler, BC, Canada, p. 1110, http://accelconf.web.cern.ch/AccelConf/SRF2015/papers/thpb021.pdf

9. Yao, Z., Laxdal, R.E., 2017 "Design and Fabrication of Balloon Single Spoke Resonator", talk at the *SRF2017,* Lanzhou, China http://accelconf.web.cern.ch/AccelConf/srf2017/talks/thxa02_talk.pdf

10. Cui, T.J., Smith, D., Liu, R., 2010, Metamaterials: Theory, Design, and Applications, ISBN-13:978-1441905727, Springer, https://www.springer.com/gp/book/9781441905727

34. HIGH ENERGY PHYSICS ELECTRONICS

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

High Energy Physics experiments require advanced electronics and systems for the recording and processing of experimental data. As an example, high-priority future experiments in the DOE Office of High Energy Physics portfolio need advances that can benefit from small business contributions. These experiments include potential upgrades to the High Luminosity Large Hadron Collider (HL-LHC) detectors currently under construction (see https://home.cern/science/accelerators/large-hadron-collider) or other potential future High Energy Colliders, neutrino experiments including those sited deep underground (e.g., https://www.dunescience.org), next generation direct searches for dark matter, and astrophysical surveys to understand dark energy, including cosmic microwave background experiments.

We seek small business industrial partners to advance the state of the art and/or increase cost effectiveness of instrumentation needed for the above experiments and for the wider HEP community. Specific technical areas are given in the subtopics below. These are areas where experimental needs have been defined and shortcomings of existing technology identified. R&D seeking new technology will typically be in progress at

DOE national laboratories and/or DOE-funded universities. While the subtopics offer initial guidance about specific technology areas, the scientists involved are the best source of detailed information about requirements and relevance to the experimental programs listed above. Applicants are therefore urged to make early contact with lab and university scientists in order to develop germane proposals. Clear and specific relevance to high energy physics programmatic needs is required, and supporting letters from lab and university scientists are an excellent way to show such relevance. Direct collaboration between small businesses and national labs and universities is strongly encouraged. For referral to lab and university scientists in your area of interest contact: Helmut Marsiske, helmut.marsiske@science.doe.gov
Grant applications are sought in the following subtopics:

a. Radiation Hard CMOS Sensors and Engineered Substrates for Detectors at High Energy Colliders

Silicon detectors for high energy physics are currently based on hybrid technology, with separately fabricated diode strip or pixel sensors and bump-bonded Complementary Metal Oxide Semiconductor (CMOS) readout chips. As larger area detectors are required for tracking and also for new applications such as high granularity calorimetry, lower manufacturing cost is needed.

For use in high energy physics, detectors must withstand both ionizing and displacement damage radiation, and they must have fast signal collection and fast readout as well as radiation tolerance in the range 100 to 1000 Mrad and 1E14 to 2E16 neutron equivalent fluence.

Of interest are monolithic CMOS-based sensors with moderate depth (5-20 micron) high resistivity substrates that can be fully depleted and can achieve charge collection times of 20 ns or less. Technologies of interest include deep n- and p-wells to avoid parasitic charge collection in CMOS circuitry and geometries with low capacitance charge collection nodes. We aim for stitched, large area arrays of sensors with sensor thickness less than 50 microns and pixel pitch of less than 25 microns.

Also of interest are low to moderate gain (x10-50) reach-through silicon avalanche diodes (LGADs) as a proposed sensor type to achieve ~10 ps time resolution for collider experiments. The current generation of reach-through diodes suffers from large fractional dead area at the edges of the pixel and only moderate radiation hardness. A moderately doped thin buried (~5 micron) layer replacing a reach-through implant can address some of these problems. We seek substrate fabrication technologies to improve the radiation hardness and stability of these devices by using graded epitaxy or wafer bonding to produce a buried and moderately doped (1E16) thin buried gain layer on a high resistivity substrate. We also seek techniques to arrange internal doping of detectors by multiple thick epitaxial layers or other methods to allow engineering of the internal fields and resulting pulse shape.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

b. CCD and CMOS Imagers for Dark Matter and Astrophysics Research

Charge-Coupled Devices (CCDs) are used in astrophysics and direct dark matter detection. The optimum sensors are fully depleted high resistivity devices, which require a backside junction. While CCDs have been the detector of choice for noise performance, CMOS imagers offering similar performance, with an emphasis on low noise, will be considered. These devices are also of interest in space science and nuclear nonproliferation applications. Specific areas of interest are: 1) Processes suitable for applications demanding a very thin entrance window junction. The standard foundry processes do not provide double sided processing. Adding the junction after the front-side processing has been completed is problematic, because the temperature necessary to activate the dopant would damage the CCD structure on the front side. Proposals are sought for novel, robust, cost-effective process technologies to enable backside junction activation at temperatures below 400 C, and that are compatible with post-foundry substrates and both CCD and CMOS sensors. MBE and laser anneal technologies are specifically excluded from this call; 2) Proposals are sought for technologies to increase the active mass of semiconductor-based dark matter detectors using fully depleted imagers. Current devices are based on silicon CCDs. Fabrication of thick (2-5 mm), large area (~10 cm x 10 cm), low noise (<few electron) silicon imaging sensors (CCDs, CMOS) could be transformative in reducing the cost and complexity of dark matter experiments based on these devices, as well as having application in nuclear nonproliferation and space sciences mission areas. We seek proposals to develop few-mm thick CCDs or CMOS imaging devices fabricated on ultra-high-resistivity silicon to produce very thick, fully depleted devices that have similar performance as current SOTA devices; and 3) Very low radiometric backgrounds are needed for dark matter experiment applications, and recent studies have revealed high levels of tritium isolated to specific processing steps in current state of the art (SOTA) devices. Reduction of radiometric backgrounds through improved material control during processing including the possible post-processing of wafers that replace the backside gettering layer with an ohmic contact layer that does not contain H_2.

Proposals that address multiple facets relevant to a single application are encouraged. Split-foundry approaches to address these needs will be considered.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

c. Characterization of Semiconductor Materials for Dark Energy and Dark Matter Detectors

Proposals are sought for non-destructive minority carrier lifetime measurements in silicon, germanium, gallium arsenide, and possibly other semiconductor materials for HEP detectors. In terms of new material development, work is underway on the production of 150mm high-purity Ge wafers for CCDs and direct x-ray detection as well as specialized GaAs substrates for scintillation applications. Semiconductor devices are extremely sensitive to metal contamination that can lead to charge trapping and dark current generation sites. Measurements of minority carrier lifetime provide a rapid means to quantify the quality of the semiconductor substrates, for assessing both the as-received material as well as the effects of processing on the carrier lifetime.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

d. High Density Chip Interconnect Technology

With the large channel counts and fine granularity of high energy physics detectors, there is an ever-increasing need for new technologies for high-density interconnects.

Grant applications are sought for the development of new technologies for reducing cost while increasing the density of interconnection of pixelated sensors to readout electronics by enhancing or replacing solder bump-based technologies. Development of cost-effective technologies to connect arrays of thinned integrated circuits (< 50 microns, with areas of ~2x2 cm^2) to high-resistivity silicon sensors with interconnect pitch of 50 microns or less are of interest. Technologies are sought that can minimize dead regions at device edges and/or enable wafer-to-wafer interconnection, by utilizing 3D integration with through-silicon vias or other methods. Present commercial chip packaging and mounting technologies can, at cryogenic temperatures, put mechanical stress on the silicon die which distort the operation of the circuit. Low cost and robust packaging and / or interconnect solutions that did not introduce such stresses would be of advantage – especially in the case of large area circuit boards (> 0.5 m on each edge).

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

e. Radiation-Hard High-Bandwidth Data Transmission for Detectors at High Energy Colliders

Detector data volumes at future colliders will be nearly 100 times more than today. Single subdetectors will have to transmit 10s to 100s of Tbps. While commercial off the shelf data transmission solutions will deliver the needed performance in the near future, these products cannot be used in future colliders for two main reasons: they will not function in a high radiation environment (hundreds of Mrad), and they are in general too massive to be placed inside detectors, where added mass degrades the measurements being made. Two main industrial developments are therefore of interest: very low mass, high bandwidth electrical cables, and radiation hard optical transceivers. The issue of radiation hardness must be addressed satisfactorily in the proposal for it to be considered responsive.

Electrical cables may be twisted pair, twinax, etc., with as low as possible mass (and therefore small size) while compatible with multi-Gbps per lane transmission over distances up to 10m. Cable fabrication using aluminum, copper clad aluminum, or non-metallic conductors (such as CNT thread), is of interest. Many dielectrics are not radiation hard, so fabrication with non-standard dielectrics is important.

Optical transceivers up to 100 Gbps will be needed. Many off the shelf commercial products meet or exceed the required bandwidth, but contain circuits that fail when exposed to ionizing radiation doses of hundreds of Mrad. Radiation hardened versions of commercial transceivers (or equivalent) are therefore of interest, where radiation hardness is achieved without adding mass or increasing size, for example by design changes to the integrated circuits used, specifically radiation hard device modeling and library development of deep sub-micron CMOS fabrication processes.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

f. Electronics and Frequency Multiplexed DAQ Systems for Low-Temperature Experiments

Many HEP experiments are operated in the deep cryogenic regime (10-100 mK) with large numbers of readout channels required. Data acquisition and controls signals from the mK stage out to room temperature require high-fidelity RF signals, extremely low noise, and low thermal load on the cryogenic systems. Applications range from future CMB experiments that will have large focal plane arrays with ~500,000 superconducting detector elements, to axion dark matter searches with similar channel count to reach to high axion masses, to large-scale phonon-based WIMP dark matter searches.

Specific areas of interest include: Low-noise cryogenic amplifiers (HEMT, SQUID, Parametric, etc.); High-density cryogenic interconnects for mK to LHe temperature stages; Scalable high-density superconducting interconnects for micro-fabricated superconducting devices; High-frequency superconducting flex circuits; Specialized electronics for processing large numbers of frequency-domain multiplexed RF signals; Wafer processing combining niobium metal and MEMS; and Fabrication of miniature, ultra-low loss, superconducting resonator arrays.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

g. High-Channel Count Electronic Tools for Picosecond (ps) Timing

High precision timing measurements in next generation detectors will require the development of circuitry to measure time to 1 ps or better over channel counts that may exceed 100,000. In addition, a method to distribute a stable reference clock with jitter of 5 ps of less and precise frequency stabilization is needed. Such a clock system needs to distribute the clock to multiple detector components distributed by distances of order ten to twenty meters. Custom radiation-hard ASIC devices will eventually be needed for many such high precision uses, but non-radiation hard demonstration systems meeting ps sensitivity and stability are of immediate interest.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

h. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

References:

1. Topical Workshop on Electronics for Particle Physics (TWEPP18), 2018, Antwerpen, Belgium. https://indico.cern.ch/event/697988/

2. WIT2010 Workshop on Intelligent Trackers, 2010, Journal of Instrumentation, Berkeley, CA, http://iopscience.iop.org/1748-0221/focus/extra.proc7

3. 23th International Conference on Computing in High Energy and Nuclear Physics (CHEP), 2018, Sofia, Bulgaria. https://indico.cern.ch/event/587955/

4. 14th Pisa Meeting on Advanced Detectors, 2018, La Biodola, Isola d'Elba, Italy, https://agenda.infn.it/event/17834/

5. International Conference on Technology and Instrumentation in Particle Physics 2017 (TIPP2017), 2017, Beijing, China, http://tipp2017.ihep.ac.cn/

6. 21st IEEE Real-Time Conference, 2018, Williamsburg, VA, https://indico.cern.ch/event/543031/

7. 15th Vienna Conference on Instrumentation, 2019, Vienna, Austria, https://vci2019.hephy.at/home/

35. HIGH ENERGY PHYSICS DETECTORS AND INSTRUMENTATION

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

High Energy Physics experiments require specialized detectors for particle and radiation detection. As an example, high-priority future experiments in the DOE Office of High Energy Physics portfolio need advances that can benefit from small business contributions. These experiments include potential upgrades to the High Luminosity Large Hadron Collider (HL-LHC) detectors currently under construction (see https://home.cern/science/accelerators/large-hadron-collider) or other potential future High Energy Colliders, neutrino experiments including those sited deep underground (e.g., https://www.dunescience.org), next generation direct searches for dark matter, and astrophysical surveys to understand dark energy, including cosmic microwave background experiments.

We seek small businesses to advance the state of the art and/or increase cost effectiveness of detectors needed for the above experiments and for the wider HEP community. Specific technical areas are given in the subtopics below. These are areas where experimental needs have been defined and shortcomings of existing technology identified. Improvements in the sensitivity, robustness, and cost effectiveness are sought. R&D towards these ends will typically be in progress at DOE national laboratories and/or DOE-funded universities. While the subtopics offer initial guidance about specific detector areas, the scientists involved are the best source of detailed information about requirements and relevance to the experimental programs listed above. Applicants are therefore urged to make early contact with lab and university scientists in order to develop germane proposals. Clear and specific relevance to high energy physics programmatic needs is required, and supporting letters from lab and university scientists are an excellent way to show such relevance. Direct collaboration between small businesses and national labs and universities is strongly encouraged. For referral to lab and university scientists in your area of interest contact: Helmut Marsiske, helmut.marsiske@science.doe.gov.

Grant applications are sought in the following subtopics:

a. Low-Cost, High-Performance Visible/(V)UV/Near-IR Photon Detection

Detectors for particle physics need to cover large areas with highly sensitive photodetectors. Experiments require combinations of the following properties: 1) Wavelength sensitivity in the range 100 to 1100 nm over large photosensitive areas; 2) Fast response, radiation hardness, magnetic field compatibility, and high quantum efficiency for collider and intensity frontier experiments; 3) Compatible with cryogenic operation and built with low-radioactivity materials for neutrino and dark matter experiments; and 4) Low cost and high reliability.

Technologies using modern manufacturing processes and low cost materials are of interest. These include use of semiconductor-based avalanche photodiodes (APD) and Geiger mode APD arrays, SiPM arrays, large area microchannel plate-based systems, new alkali and non-alkali photocathode materials, and high volume manufacturing of large-area, ultra clean, sealed vacuum assemblies.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

b. Scintillating Detector Materials and Wavelength Shifters

High Energy Physics utilizes scintillating materials for large calorimeters in colliding beam and intensity frontier experiments as well as the active medium in some neutrino and dark matter detectors. Development of radiation-hard (tens of Mrad), fast (tens of ns) scintillators and wavelength shifting materials is of particular interest for colliding beam experiments. Development of fast (tens of ns), wavelength-matched shifting materials is of interest for liquid argon and liquid xenon detectors for neutrinos and dark matter. Bright (>10,000 ph/MeV), fast (tens of ns), radiation-hard (tens to hundreds of Mrad) crystals or ceramics with high density (>6 g/cm^3) are of interest for intensity frontier experiments as well as colliding beam experiments if cost-effective production methods can be developed.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

c. Cost-Effective, Large-Area, High-Performance Dichroic Filters

Water- and scintillator-based neutrino detectors have for decades used photons to observe neutrino interactions; however, very little information about the photons is actually used. By wavelength sorting photons using dichroic filters one can provide additional information, such as the source of the light and its travel time. In particular, by building a Winston cone from dichroic mirrors, the “dichroicon”, one can sort long wavelength photons (cut-on wavelength 450-500 nm) towards a central PMT and, for example, separate the Cherenkov and scintillation components of the light produced in a liquid scintillator detector. In order to use the dichroicon, future detectors, such as THEIA, will require large-area dichroic filters at a low cost and with improved transmissive and reflective properties (both >95% for wavelengths 300-600 nm). Dichroic filters have also become part of the baseline design for DUNE's photon system, where they will be used to “trap” photons and enhance light collection. DUNE will also need a large quantity of these, and large-area versions will enhance its physics program by further increasing light collection. High-integrity filter cutting with the ability to deposit dichroic material on large surfaces (~10’s of cm^2) will help enable this technology.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

d. Ultra-Low Mass, High-Rate Charged Particle Tracking

High intensity experiments searching for very rare phenomena, such as neutrino-less coherent muon-to-electron conversion and muon decays to e+e-e- or to e- gamma, require precision charged particle tracking at low momenta in the 10 - 100 MeV/c range. Momentum resolutions of 0.1% are required in order to mitigate steeply falling physics backgrounds, necessitating ultra-low mass designs. We seek technologies capable of achieving 10-100 micron position resolution while operating in vacuum and handling average rates from 10 kHz/cm^2 to 1 MHz. /cm^2. The mass of these sensors and associated cooling and cabling must correspond to less than 50 microns of silicon per detector layer. Technologies to be considered include gas-filled aluminized mylar tubes with wall thickness less than 10 microns and thinned CMOS sensors. We also seek cooling technologies for CMOS sensors able to extract heat (~50-100 mW) to remote (~1 meter) heat sinks with minimal mass.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

e. Ultra-Low Background Detectors and Materials

Experiments searching for extremely rare events such as nuclear recoils from WIMP dark matter particles or neutrino-less double beta decays require that the detector elements and the surrounding support materials exhibit extremely low levels of radioactivity. The presence of even trace amounts of radioactivity in or near a detector induces unwanted effects. New instruments and techniques are needed and may include: 1) Instruments to measure ultra-low-backgrounds of gamma, neutron and alpha particles; 2) Improvements in the ability to measure and control radon or surface contamination; 3) Development of ultra-radio-pure materials for use in detectors; and 4) Manufacturing methods and characterization of ultra-low- background materials.

Grant applications are sought to develop plastic solids and parts from high purity, low radioactivity polymer raw materials, where the resulting solids and parts preserve the low radioactivity of the original plastic resins or powders. Plastics should have mechanical properties equal to or better than polyvinylidene fluoride (PVD), and ideally comparable to polyetheretherketones, polyaromatic etherketones, polyimides, polyetherimides, and polyamideimides. Many components for ultra-low background radiation detectors, used for detecting rare events in physics, must be made from insulating materials with low radioactivity. Their uses include functions as structural components, or as substrates and parts of electronic assemblies. Conventional methods such as injection molding or extrusion involve intimate contact between molten polymer resins and hot metal surfaces, sometimes with additives present, leading to solids that are significantly more radioactive than the original polymer resins or powders. The radio-contaminants include natural uranium and thorium introduced in dust, radon as a gas and subsequent progeny implanted during radioactive decay, and potassium from human contact and present in many oils and other solutions used in processing. Various 3D printing techniques could significantly reduce or eliminate the introduction of radio-contaminants in the processing from high purity, low radioactivity powders to finished parts.

Grant applications are sought for the development of low-radioactivity liquid scintillator cocktails that avoid high volatility solvents and are not environmental pollutants. One of the most radio-pure liquid scintillators to date was produced by the Borexino experiment, but the solvent is pseudocumene, which has a very low flash point and is a severe marine pollutant. Due to safety concerns, the use of hazardous materials is being either limited or completely eliminated at underground physics laboratories. However, the need still remains, and a direct replacement does not exist commercially. This includes the use of liquid scintillators in active veto detectors, or as the primary detection material. A stretch goal is to reach uranium and thorium levels of approximately 10^{-16} g/g, and the ability to distinguish between gamma and neutron events is highly desirable. For some applications, the scintillator must also be water miscible.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

f. Advanced Composite Materials

Ultimate-performance mechanical materials for precision support and cooling are of general interest for HEP detectors. Mechanical structures are used to hold detector elements with micron precision and stability, with as close to zero mass as possible. Of interest are: novel low-mass materials with high thermal conductivity (>20 Wm/K for 0.1 g/cc) and stiffness; adhesives with very high thermal conductivity (>5 Wm/K) and radiation tolerance (>100 Mrad); low mass composite materials with good electrical properties for shielding, data transmission or power conduction; and radiation tolerant (>100 Mrad) low loss dielectric materials. Improvements to manufacturing processes to take advantage of new or recently developed materials, and performance and stability from room temperature to cryogenic temperatures (70 K and 4 K) are of interest. Also of interest are light-weight, radiation-hard carbon fiber structures (or other metamaterials) with Negative Thermal Conductivity for more efficient cooling of collider tracking detectors and better shielding from thermal noise in Cosmic Microwave Background or Dark Matter experiments.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

g. Additive Manufacturing

Instruments (detectors and optics) for High Energy Physics experiments are often characterized by large areas or large volumes, need exquisite performance and need to be composed of materials that have to withstand harsh conditions, such as ultra-cold, high pressure or high radiation. Additive manufacturing technologies using Powder Bed Fusion, based on selected laser melting or electron beam melting, or Direct Energy Deposition manufacturing, based on laser or e-beam, using a powder or wire-fed process, and low-loss dielectrics (e.g., silicon, alumina, and ceramics) are of interest to address critical technical challenges in HEP. Areas of particular relevance are embedded cooling structures, low-mass support structures and micro-capillary arrays, support structures with high thermal conductance and low thermal contraction, and low-loss dielectric optics with built-in anti-reflection coatings for mm-wave transmission.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

h. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

References:

1. Demarteau, M., Lipton, R., Nicholson, H., et al, 2013, Instrumentation Frontier Snowmass Report, Planning the Future of U.S. Particle Physics, p. 44, https://www.academia.edu/18214873/Planning_the_Future_of_US_Particle_Physics_Snowmass_2013_Chapter_8_Instrumentation_Frontier

2. Demarteau, M. and Shipsey, I., 2019, New Technologies For Discovery – A report of the 2018 DPF Coordinating Panel for Advanced Detectors (CPAD) Community Workshop, https://cds.cern.ch/record/2688980/?ln=en

3. Formaggio, J.A. and Martoff, C.J., 2004, Backgrounds to Sensitive Experiments Underground, Annual Review of Nuclear and Particle Science, Volume 54, p. 361-412, http://www.annualreviews.org/doi/abs/10.1146/annurev.nucl.54.070103.181248?journalCode=nucl

4. International Conference on New Photo-Detectors, 2015, PhotoDet 2015, Moscow, Troitsk, Russia, http://pd15.inr.ru/

5. 8th Trento Workshop on Advanced Silicon Radiation Detectors (3D and P-type), 2013, TREDI2013, Fondazione Bruno Kessler Research Center, Trento, Italy, http://tredi2013.fbk.eu/

6. Balbuena, J.P., Bassignana, D., Campabadal, F., et al, 2012, Radiation Hard Semiconductor Devices for Very High Luminosity Colliders, RD50 Status Report 2009/2010, Report Numbers: CERN-LHCC-2012-010, LHCC-SR-004, p. 29. http://cds.cern.ch/record/1455062/files/LHCC-SR-004.pdf

7. Hartmann, F. and Kaminski, J., 2011, Advances in Tracking Detectors, Annual Review of Nuclear and Particle Science, vol. 61, p. 197-221. http://www.annualreviews.org/doi/abs/10.1146/annurev-nucl-102010-130052

8. Brau, J.E., Jaros, J.A., Ma, H., 2010, Advances in Calorimetry, Annual Review of Nuclear and Particle Science, Vol. 60, p. 615-644. http://www.annualreviews.org/doi/abs/10.1146/annurev.nucl.012809.104449

9. Kleinknecht, K., 1999, Detectors for Particle Radiation, 2nd ed., Cambridge University Press, Cambridge, MA, p. 260, ISBN 978-0-521-64854-7, https://www.gettextbooks.com/isbn/9780521648547/

10. Knoll, G.F., 2010, Radiation Detection and Measurement, 4th ed., J. Wiley & Sons, Hoboken, NJ, p. 864, ISBN 978-0-470-13148-0. http://www.wiley.com/WileyCDA/WileyTitle/productCd-EHEP001606.html

11. Spieler, H., 2005, Semiconductor Detector Systems, 1st ed., Oxford University Press, New York, NY, p. 512, ISBN 978-0-198-52784-8, http://www.amazon.com/Semiconductor-Detector-Systems-Science-Technology/dp/0198527845/ref=sr_1_1?ie=UTF8&qid=1412782151&sr=8-1&keywords=9780198527848

12. The 17th International Workshop on Low Temperature Detectors (LTD17), 2017, Kurume City Plaza, Fukuoka, Japan, http://www-x.phys.se.tmu.ac.jp/ltd17/wp/

13. Bartolo, P.J., 2011, Stereolithography: Materials, Processes and Applications, Springer, Boston, MA, p. 340, ISBN 978-0-387-92903-3. http://link.springer.com/book/10.1007%2F978-0-387-92904-0

14. 14th Pisa Meeting on Advanced Detectors, 2018, La Biodola, Isola d'Elba, Italy, http://www.pi.infn.it/pm/2018/

15. International Conference on Technology and Instrumentation in Particle Physics 2017 (TIPP2017), 2017, Beijing, China, http://tipp2017.ihep.ac.cn/

16. IEEE Symposium on Radiation Measurements and Applications (SORMA WEST2016), 2016, Berkeley, CA, http://sormawest.org/

17. 15th Vienna Conference on Instrumentation, 2019, Vienna, Austria, http://vci2019.hephy.at/home/

36. QUANTUM INFORMATION SCIENCE (QIS) SUPPORTING TECHNOLOGIES

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

Quantum science and instrumentation for next-generation computing, information, and other fields—the core of "quantum information science" (QIS)—are developing rapidly and present numerous opportunities for impacts in high energy physics. Quantum sensors and controls, analog simulation, and qubit systems that specifically rely on or exploit superposition, entanglement, and squeezing of physical states are of particular interest. This topic focuses on key technologies to support quantum information systems that build on experience in high energy physics experimental systems, and on further development of quantum information systems for application in precision measurement, simulation, and computation that advances high energy physics research.

Grant applications are sought in the following subtopics:

a. Development of Optimal SRF Cavity Geometries for Quantum Information Systems

One promising architecture for quantum computing involves superconducting Josephson-junction-based qubits enclosed by superconducting 3D microwave resonators, currently providing the longest coherence times among all superconducting qubits. Achieving the highest possible quality factor Q of the host resonators is one of the identified high impact directions for improving the coherence time of the cavity-qubit systems, as the superconducting resonator serves as a “shield” to isolate the qubit from environmental de-coherence. Furthermore, high-Q cavities have been proposed as possible “quantum memories” where information about the quantum state can be stored during computations. A typical frequency range for superconducting qubit operation is 6 GHz to 15 GHz. 3D niobium SRF cavities, similar to those used in particle accelerators, should be able to provide high quality factors in this frequency range. However, existing cavity geometries are optimized for particle acceleration rather than hosting qubits. Grant proposals are sought for development of 3D SRF cavity geometries in the frequency range of 6 GHz to 15 GHz for hosting superconducting Josephson-junction-based qubits. The geometries should be suitable for scalability from a single SRF cavity-qubit unit to multi-qubit systems.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

b. Optimization of Fabrication Techniques for Scalable 3D SRF Structures for Quantum Information Systems

Traditionally, 3D niobium SRF cavities for particle accelerators are fabricated using electron beam welding of stamped/hydro-formed parts. This approach works well at frequencies below 3.9 GHz. However, future quantum information science (QIS) systems will likely operate in the frequency range of 6 GHz to 15 GHz and will consist of many individual cavity-qubit units coupled together. It is very important to re-assess the cavity fabrication and develop new techniques suitable for high-frequency, scalable SRF structures for QIS. An example of such technique could be precise machining of split-cell-like structures. Grant proposals are sought to develop cavity fabrication techniques optimized for scalable 3D SRF structures for QIS...

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

c. Development of Low-Temperature Technologies for QIS Systems

Cryogenic QIS systems operating near or below one Kelvin (1 K) are growing in scope and cold mass, and potentially include next generation cosmic microwave background (CMB) detectors, dark matter search detectors, some qubit systems for quantum computing, and other quantum sensor technologies operating in the milli-Kelvin (mK) range. Grant proposals are sought for the development of: (1) 4He/3He hybrid refrigeration systems that can efficiently sink power at both 1 K and mK temperatures, likely requiring separating the dilution refrigerator circuit from a separate 1 K cryogenic system; (2) High Density Interconnect (HDI) cables for microwave and RF readouts (frequencies ~1 – 10 GHz) operating with high bandwidth and low thermal loss at mK temperatures that transition to 1 K temperatures; (3) low-power mechanical actuators that can operate at mK temperatures with low thermal loss; (4) low-noise electrical circuit switches operating at mK temperatures with injected noise at the few-quanta noise level; (5) low-noise electronics for excitation and front-end readout of transmon/SRF cavity multi-qubit systems; (6) Cryogenic device modeling and library development of deep sub-micron CMOS fabrication processes operating at 100 mK – 4 K.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

d. Photodetectors for Optical to Microwave Transduction of Quantum Information

Improvements in microwave detection can be applied to cosmic microwave background and axion detection, and may be enabled by QIS-based approaches. While substantial quantum squeezing can be produced optically, the ability to write that information onto microwave photons in a cavity would enhance the readout of microwave detectors. With improvements in transduction of quantum information, entanglement could also be distributed among many distant microwave resonators to create a very large sensor network (using entangled photons). Transduction of the full state would allow for preserving entanglement and other properties from microwaves to optics and back. Many of these features could be achieved with unidirectional transduction. Grant proposals are thus sought for production, testing, and/or validation of photodetector systems with high speed (>5GHz) and high quantum efficiency (>95%) capable of detecting continuous variable quantum information and writing it onto microwave photocurrents that are compatible with microwave cavities. Devices that can coherently transduce a quantum state from photonic to microwave degrees of freedom, or vice versa, are sought. Proposers must demonstrate unidirectional devices with 50% or more fidelity in transduction of the quantum state.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

e. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

References:

1. National Science and Technology Council (NSTC) report, 2016, Advancing Quantum Information Science: National Challenges and Opportunities, https://www.whitehouse.gov/sites/whitehouse.gov/files/images/Quantum_Info_Sci_Report_2016_07_22%20final.pdf

2. National Science and Technology Council (NSTC) report, 2018, National Strategic Overview for Quantum Information Science, https://www.whitehouse.gov/wp-content/uploads/2018/09/National-Strategic-Overview-for-Quantum-Information-Science.pdf

3. HEP-ASCR Study Group Report, 2015, Grand Challenges at the Interface of Quantum Information Science, Particle Physics, and Computing, U.S. Department of Energy, Office of Science, http://www.theory.caltech.edu/people/preskill/talks/Preskill-HEPAP-2015.pdf

4. DOE HEP-ASCR QIS roundtable Report, 2016, Quantum Sensors at the Intersections of Fundamental Science, QIS and Computing, U.S. Department of Energy, Office of Science, https://www.osti.gov/servlets/purl/1358078

5. Coordinating Panel for Advanced Detectors of the Division of Particles and Fields of the American Physical Society, 2018, Quantum Sensing for High Energy Physics: Report of the first workshop to identify approaches and techniques in the domain of quantum sensing that can be utilized by future High Energy Physics applications to further the scientific goals of High Energy Physics, https://lss.fnal.gov/archive/2018/conf/fermilab-conf-18-092-ad-ae-di-ppd-t-td.pdf

6. DOE HEP Request for Information: Impacts from and to Quantum Information Science in High Energy Physics, 2018, RFI and responding comments, https://www.regulations.gov/docket?D=DOE-HQ-2018-0003

Return to Table of Contents

PROGRAM AREA OVERVIEW – OFFICE OF NUCLEAR ENERGY

The primary mission of the Office of Nuclear Energy (NE) is to advance nuclear power as a resource capable of meeting the Nation's energy, environmental, and national security needs by resolving technical, cost, safety, proliferation resistance, and security barriers through research, development, and demonstration as appropriate.

NE's programs are guided by three priority focus areas:

(1) Maintaining the current nuclear reactor fleet;
(2) Encouraging growth for a new advanced reactor pipeline (both near- and longer-term), including through the employment of key private-public partnerships; and,
(3) Redeveloping America's nuclear fuel cycle, infrastructure, and supply chain.

Nuclear energy is a key element of United States (U.S.) energy independence, energy dominance, electricity grid resiliency, national security, and clean baseload power. America's nuclear energy sector provides over 60 percent of the nation's annual clean electricity production, generates nearly 20 percent of U.S. electricity from a fleet of 99 operating units in 30 states, supports 500,000 jobs, and contributes $60 billion per year to our Gross Domestic Product (GDP). America's nuclear energy sector also plays key national security and global strategic roles for the U.S., including nuclear nonproliferation.

The Office of Nuclear Energy's SBIR/STTR workscopes also support the DOE Gateway for Accelerated Innovation in Nuclear (GAIN) initiative (see https://gain.inl.gov), which provides the nuclear energy community with access to the technical, regulatory, and financial support necessary to move new or advanced nuclear reactor designs toward commercialization while ensuring the continued safe, reliable, and economic operation of the existing nuclear fleet.

For additional information regarding the Office of Nuclear Energy priorities, click here.

37. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

New methods and technologies are needed to address key challenges affecting the future deployment of nuclear energy and to preserve U.S. leadership in nuclear science and engineering, while reducing the risk of nuclear proliferation. This topic addresses several key areas that support the development of crosscutting and specific reactor and fuel cycle technologies.

Grant applications are sought in the following subtopics:

a. Advanced Sensors and Instrumentation (Crosscutting Research)

Proposal are sought in the area of Advanced Sensors and Instrumentation (ASI) for the development of innovative technologies that support: the existing fleet of nuclear reactors, including materials test reactors; the development of advanced reactor concepts and the acceleration of advanced fuel cycle technologies commercialization. The proposed sensors and instrumentation should demonstrate greater accuracy, reliability, resilience, higher resolution, and ease of replacement/upgrade capability for applications in the nuclear environment, while striving to reduce operations and maintenance costs. The proposed technology should support the Gateway for Accelerated Innovation in Nuclear (GAIN) Initiative and be applicable to multiple reactor concepts or fuel cycle applications, i.e. crosscutting.

Applications are sought in the following areas:

1. Develop and demonstrate innovative sensors and instrumentation that can reliably operate in nuclear reactors core, primary and secondary coolant loop and other relevant plant systems. Irradiation experiments in Material Test Reactors should be considered as a valuable target for the technology demonstration and the definition of design requirements for near term deployment. The following are examples of technical areas of interest: distributed or multi-point measurement of neutron flux in reactors core during operation; distributed or multi-point measurement of nuclear fuel and reactor components temperature during operation; measurement of fission gas products inside nuclear fuel pins; measurement of dimensional changes of nuclear fuel and components during irradiation experiments in Material Test Reactors.
2. Advanced control systems that increase nuclear plant system reliability, availability, and resilience including the ability to detect and manage faults in I&C systems and plant components; state of the art control rooms, control systems, and plant control technologies. The project outcomes must enable semi-autonomous and remote operation, and advanced automation.
3. Nuclear Plant Wireless Communication technologies that securely and reliably support greater data generation and transmission demands expected to accompany advancements in digital sensor, measurement, and control technologies. This may include power harvesting, energy storage, data transmission techniques, and related methods to reduce both power cabling and communication cabling needed for sensors and communications in I&C systems.
4. Big Data analytics and Machine Learning approaches for nuclear applications to develop and demonstrate capabilities that would enable semi-autonomous and remote monitoring of nuclear plant operation and maintenance activities for advanced reactors.

Grant applications that address the following areas are NOT of interest for this subtopic and will be declined: nuclear power plant security, homeland defense or security, or reactor building/containment enhancements; radiation health physics dosimeters (e.g., neutron or gamma detectors), and radiation/contamination monitoring devices; U. S. Nuclear Regulatory Commission probabilistic risk assessments or reactor safety experiments, testing, licensing, and site permit issues.

Questions – Contact: Suibel Schuppner, Suibel.Schuppner@nuclear.energy.gov

For more information on the ASI program visit https://www.energy.gov/ne/nuclear-energy-enabling-technologies

b. Advanced Technologies for the Fabrication, Characterization of Nuclear Reactor Fuel

Improvements and advances are needed for the fabrication, characterization, and examination of nuclear reactor fuel. Advanced technologies are desired for light water reactor fuels and materials, with current emphasis on Accident Tolerant Fuel (ATF) program needs, and for advanced reactor fuels including TRISO particle fuels for Advanced Helium Gas-Cooled Reactors [1, 2, 3, 4, 5, 6, 7] and TRISO related fuel for Advanced Reactors and fuels for sodium and lead fast reactors. Specific technologies that improve the safety, reliability, and performance in normal operation as well as in accident conditions are desired.

- Provide new innovative ATF LWR fuel cladding concepts that have the potential to support achieving very-high burnups (~100,000 MWD/MTU), to include fuel and/cladding, such as improved cladding using Silicon Carbide (SiC) and other ceramics, and associated novel pellet technologies, such as with doping. Improvements to LWR fuel and cladding may include but not be limited to fabrication techniques or characterization techniques to improve the overall performance or understanding of performance of the nuclear fuel system. Cooperation is encouraged with a national lab or other entity with fuel fabrication capabilities, as production of a prototypic sample for irradiation would be required for any follow on phase.

- Develop a robust, reliable and advanced tagging or tracking method for ex-core evaluation of irradiated TRISO-fueled pebbles to include: (a) a robust method for unique identification of each irradiated pebble as it leaves the core either to be discharged for high burnup level or recycled back into the core, and (b) an advanced computational model that uses this tagging method and its data to simulate pebble flow through the core. The tagging method must be able to handle (1) potential surface abrasion or degradation, (2) the high temperature and high neutron flux environments (3) allow for rapid reading time to meet throughput requirements, and (4) track and catalogue the large number of pebbles.

  Actual irradiated TRISO fueled samples may be available for use from the Idaho National Laboratory and Oak Ridge National Laboratory Advanced Gas Reactor TRISO fuels laboratory facilities [6, 7] to demonstrate the techniques and equipment developed. Access to DOE laboratory test reactors and hot cells could be available through separate awards from the INL Nuclear Scientific User Facilities Program, and DOE NE GAIN program, or as part of a phase II SBIR/STTR award.

- Develop and/or demonstrate improved fabrication methods for sodium fast reactor fuels and cladding materials, especially for uranium and plutonium based metallic fuels that eliminate the need for sodium bonding to the cladding.

Grant applications may use non-fueled surrogate materials to simulate uranium, plutonium, and minor actinide bearing fuel pellets or TRISO particles for demonstration.

Grant applications that address the following areas are NOT of interest and will be declined: thorium based fuels, spent fuel separations technologies used in the Fuel Cycle Research and Development Program [5] and applications that seek to develop: (a) new glove boxes or sealed enclosure designs or (b) new burnup measurement monitoring systems for TRISO-fueled pebbles.

Questions – Contact: Frank Goldner, Frank.Goldner@nuclear.energy.gov

c. Materials Protection Accounting and Control for Domestic Fuel Cycles

The Materials Protection, Accounting and Control Technology (MPACT) program seeks to develop innovative technologies, analysis tools, and advanced integration methods in order to enable U.S. domestic nuclear materials management and safeguards for emerging nuclear fuel cycles and reactors. Specifically, innovative technologies and tools which enable the integration of safeguards and security features into the design and operation of nuclear fuel cycles and advanced reactors operations are being sought. Grant applications are requested for: (1) New tools and instruments for radiation detection; (2) Advanced active interrogation methods and technologies; (3) Innovative spectroscopy techniques to improve the efficiency and effectiveness of safeguards systems; (4) Novel methods for data validation, data integration, and real time analysis of facility operations.

Grant applications that address border security or remote monitoring are not sought.

Questions – Contact: Michael Reim, michael.reim@nuclear.energy.gov

d. Advanced Modeling and Simulation

Computational modeling of nuclear reactors for design and operation is becoming increasingly predictive and able to leverage high-performance computing architectures. While these tools perform similarly to legacy tools for simple problems, utilizing the advanced features of these tools requires more in-depth training, skills, and knowledge. Furthermore, in order to integrate robust multi-physics capabilities and current production tools for ease-of-use and deployment to end users, and for enabling the use of high-fidelity simulations to inform lower-order models for the design, analysis, and licensing of advanced nuclear systems and experiments, it is worthwhile to invest in technologies that ease the adoption of these modern computational tools.

Grant applications are sought that apply Office of Nuclear Energy's (NE) advanced modeling and simulation tools (https://gain.inl.gov/SitePages/ModSim.aspx) to industry challenges for increased use by industry, either light-water reactor (LWR) or advanced reactor industry. This can include:

- Facilitate access to Office of Nuclear Energy's (NE) advanced modeling and simulation tools for inexperienced users;
- Apply the results of high-fidelity simulations to inform the improved use of lower-order models as fast-running design tools;
- Provide capabilities for automated verification of numerical solutions, including mesh refinement studies; and
- Application of the tools with existing plant operational data to demonstrate the value for real-world industry applications.

Questions – Contact: David Henderson, David.Henderson@nuclear.energy.gov

e. Plant Modernization

Improvements and advancements are needed to address nuclear power plant economic viability in current and future energy markets through innovation, efficiency gains, and business model transformation. This includes transformative digital technologies that results in broad innovation and business process improvement in the nuclear light water reactor fleet's operating model. The modernization of plant systems and processes will enable a technology-centric business model platform that supports improved performance at lower cost, contributing to the long term sustainability of the LWR fleet, which is vital to the nation's energy and environmental security.

Technology should demonstrate and support improved functionality and efficiencies in plant operation and maintenance processes. This will include improvements for both core operations and maintenance work activities, as well as support functions, such as security, management, administration, procurement, and radiation protection. Effective modernization requires improved process automation, machine intelligence and computer aided decision making. To achieve this mission in the nuclear power industry, applications are sought in one of the following plant modernization areas:

- I&C modernization: Technologies are sought to reduce the burden of modernizing the I&C infrastructure through novel methods to automate or virtualize the I&C equipment replacement, function sustainability, integration, installation, and testing. In addition, technologies are sought to overcome collateral issues that arise during an I&C modernization. These solutions would address both costs and applicable regulatory concerns.

- Data use: Technologies are sought for novel sensors, devices, and methods such as blockchain to extract and manage data from nuclear power plants, which would enable advance automation of current operations and maintenance activities. The purpose of the data extracted should be to enhance the online monitoring of nuclear power plants. The technologies sought should have direct value of deployment.
- Advanced Applications: Technologies are sought to facilitate the use of tools and products that are available in other industries, yet face obstacles and challenges to be utilized by the nuclear power industry. Examples of the sought technologies are intelligent tools to automate the conversion of work packages to electronic work packages with minimal human involvement, smart scheduling technologies that recognizes patterns and provide a machine-intelligent scheduling functions for nuclear power plants.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

f. Materials R&D

1. Repair and maintenance of key components in the US fleet of nuclear power plants is critically important for aging management and sustainable plant operation. Weld repairs of those key components is a potential method for mitigating cracking or degradation instead of component replacement. The primary focus of this call is repair welds to improve resistance to stress corrosion cracking and long-term materials degradation. Additionally, new and improved welding techniques are needed to avoid and/or reduce deleterious effects associated with traditional welding fabrication practices particularly associated with helium induced cracking of irradiated materials.

   The DOE Light Water Reactor Sustainability Program has been working in collaboration with the Electric Power Research Institute to develop and assess the ability of friction stir welding (including friction stir cladding) and advanced laser welding techniques to be used for highly irradiated materials. This call seeks proposals that would develop the means for deploying this technology for reactor component repair. Phase I seeks to provide a feasibility evaluation of weld systems used in underwater conditions and an initial design study for a system of deployment. Phase II work would focus on developing and demonstrating the prototype system using a scale mock-up of potential reactor areas where weld repair would likely be needed.

2. Nondestructive examination (NDE) techniques for in-situ monitoring of cable insulation is an important component of aging management and sustainable operation of the US nuclear power plant fleet. This call seeks proposals focused on the development and improvement of online cable monitoring methods for aging management, reduced cost, and/or improved reliability.

   Several methods exist for determining the condition of installed cables of importance in an operating nuclear power plant, both at accessible locations along the length of the cable and of bulk cable health from the terminal ends of cables. Most cable analysis methods, however, are applied when the cables are not energized and often with cables disconnected from their circuits. The ability to monitor cable condition on-line (continuously during operation) or at least without disconnecting or de-energizing the cables could greatly reduce the time and expense associated with cable monitoring. Utilization of such methods may not only reduce cable aging management costs but could increase operational safety and maintenance efficiency through enabling a larger fraction of plant cables to be assessed simultaneously or per outage.

Examples of possible methods include:

i. fiber optics for distributed temperature sensing of component local environments;
ii. on-line spread spectrum time domain reflectometry for circuit health monitoring;
iii. on-line FDR (frequency domain reflectometry) or JTFDR (joint time-frequency domain reflectometry);
iv. on-line partial discharge testing for low/medium voltage cables

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

g. Flexible Plant Operation & Generation

The path to clean energy hubs that convert nuclear and renewable energy and renewable biomass into fuels and manufactured consumer products requires revolutionary systems integration and demonstration of new technologies and process innovations. Integrated energy systems that will enable nuclear plants to swing between power generation and direct energy supply to an industrial manufacturing plant are being advanced by the Department of Industry in association with nuclear plant owners and industrial partners. Flexible plant operations and generation will enable nuclear power plants to optimize their revenue by dynamically responding to modern grid markets that are realizing higher penetration of renewable energy and natural gas power plants. Three areas of technology development are needed.

1. Advanced or new technologies that safely and efficiently transfer heat and transport this energy to an industrial user are needed. The technologies need to be able to handle rapid transients in energy delivery. Heat exchanger designs are needed to transfer the energy from the steam lines in the secondary side of either pressurized water reactor design or boiling water reactor designs to a secondary heat transfer loop that deliver the heat.
   Concepts are needed for NQA1-qualifed heat exchanger to safely and efficiently transfer heat and transport this energy to an industrial user are needed. Heat exchangers must withstand temperature transients (25-325 C); pressure differences (0- 6.0 MPa - gauge), and pressure oscillations (0 – 0.1 MPa – gauge; 0 – 0.1 Hz). Heat exchangers shall be constructed of materials that pass ASTM codes and other standards relative to corrosion, creep, and fatigue resiliency for long-service operations. Materials joining, flanges or other coupling must also comply with ASTM and nuclear industry standards. Heat exchangers shall be designed for LWR main steam process lines and re-heat lines with pressures ranging from 0- 6.0 MPa. The heat exchangers will transfer thermal energy to secondary-side pressurized water, steam, synthetic oils, or molten salt thermal hydraulic loops. Heat exchangers shall inhibit tritium migration to the secondary side medium. Heat exchangers shall be scalable in systems ranging from 1 MW-100 MW (thermal energy).

2. Robust control valves with rapid and precise response time constants, precise proportional control, accurate instrumentation, and wireless signal transmission are needed to dispatch thermal energy from the secondary side thermal hydraulic and power systems of a nuclear power plant to an independent, close-coupled thermal energy user. The control valves need to be fast actuating, robust with high reliability and low maintenance, and scalable for large steam lines that bypass the power generation turbines.
   Concepts are needed for NQA1-qualified steam bypass control values with rapid response time constants for precise proportional dispatch of steam to a tertiary thermal energy supply system at a

nuclear power plant. Control values that can proportionally adjust from 5-95% of flow capacity within 5-10 minutes are needed. Control vales need to include accurate positioning and integral flow measurements with instantaneous signal transmission to control systems. Self-correcting controls may be included to dampen flow perturbations and to rapidly achieve desired flow ranges.

3. Advanced automatic control systems with appurtenant instrumentation and data signals transmitters and data fusion and data interpretation are needed for responsive thermal energy dispatch systems. The goal is for the automatic system to continuously measure and diagnose thermal energy delivery systems stability. The control systems need to interface with LWR plant supervisory control systems. The joint control environments need to rapidly perform thermal energy dispatch to enable LWRs to flexibly provide load-following and to function as spinning or non-spinning reserves when apportioning steam between power generation and a second, non-power generation thermal energy user. Recommended language for the SBIR call:
   Concepts are needed for advanced automatic control systems that rapidly dispatch thermal energy between power generation and a second thermal energy user. Controls systems must enable LWRs to rapidly dispatch power to the grid with response characteristics suitable to provide spinning or non-spinning reserves when apportioning steam between power generation and a second, non-power generation thermal energy user. Communications interfaces with LWR reactor control and power conversion stations need to be provided. Control systems designs shall include appurtenant instrumentation and data signals transmitters. Control systems shall perform necessary data fussion and data interpretation. The joint LWR and thermal energy dispatch control systems shall continuously measure and diagnose the thermal energy system stability.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

h. Nuclear Power Plant Physical Security

Improvements and advancement in nuclear power plant physical security modeling and simulation tools are needed to reduce uncertainty around adversary timelines and to account for a broader range of potential nuclear power plant facility responses. These advances in modeling and simulation tools will allow nuclear power licensees to optimize their physical security postures, maximize physical security effectiveness, allow for a broader range of facility responses, include advances in security technologies, and advance the technical basis necessary to show physical security effectiveness. Application for advances in modeling and simulation tools that directly support physical security force-on-force modeling are sought with the following attributes:

- Tools that will directly link reactor response to force-on-force modeling utilizing existing nuclear power plant reactor system response modeling and which consider operator actions, reactor physics, thermal hydraulics, or a combination of these
- Integrate into existing, or create, force-on-force modeling which can consider pathway analysis, probability of interruption, probability of neutralization, or a combination of these
- Provide a framework which can consider situational uncertainty within either reactor system response or force-on-force response as feedback to other response type models

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

i. Risk Informed Safety Analysis (RISA) FRI3D Tool Commercialization

Several U.S. National Laboratories and associated programs have successfully deployed tools developed by the Government by letting private companies manage the commercialization process (user interface, maintenance, further development, training, software support, etc.). The commercialization of software is desired to ensure that the technology is made available to the largest number of user to ensure leveraging of the Government investment in the initial software development. Proposals targeting the steps needed to bring probabilistic software applied by the Risk-Informed Systems Analysis (RISA) Pathway to commercial applicability are of interest. The response to this call should be the development toward code commercialization for the software called the Fire Risk Investigation in 3D (FRI3D) developed as part of the RISA Enhanced Fire PRA project.

FRI3D couples a nuclear power plant's existing fire model with a 3D interface to aid in visualization of scenarios, ability to add spatial information for fire risk modeling, and couple a physics-based fire simulation code CFAST in order to perform mechanistic analysis. These abilities allow users to easily construct a 3D model for a fire zone, visualize component failures for fire scenarios, and the capability to auto generate scenarios from a simulated fire is under development. The back end of FRI3D is module based and is designed to import varied format or custom plant information with minimal effort. Some capabilities of interest include in enhancing the model development process via importing of CAD models and adding visualization of the fire simulation results via the graphical interface. The proposal should also demonstrate that the proposer has the necessary technical and business aspects to develop any proposed code modification to FRI3D (e.g., QT graphical user interface development, and 3D rendering in Open GL) and to manage the code commercialization process.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

j. Component Development to Support Molten Salt Reactors

Molten Salt Reactors (MSR) represent a potential revolutionary shift in the implementation of nuclear power, and as a broad class of reactors, have the potential to directly address many US objectives. As high temperature reactors, they offer increased power conversion efficiency, high temperature process heat, reduced waste heat rejection, the possibility of dry heat rejection, and increased fissile resource utilization. MSRs can be deployed at gigawatt-scale or as small modular reactors. This flexibility, along with improved heat rejection characteristics, greatly expands siting opportunities for MSRs. Low-pressure operation with chemically inert coolants allows for thinner walled components that may be significantly less expensive. Many major plant components could potentially be replaceable. The ability to continually process fission products out of the reactor system changes the nature of accident scenarios and could allow for important innovations such as passive, walk-away safety and a meaningful reduction of site emergency planning zones. MSRs are versatile and powerful machines and can assist in closing the fuel cycle by reuse of fuel and by consumption of surplus fissile inventories.

DOE is seeking proposals for collaborative small business partnerships from a U.S. company or companies to advance Molten Salt Reactors and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Development of a small electromagnetic fuel salt pump to support either side stream processing or small experimental loops.
- Development of multi-use fuel salt flange connection suitable for connection/disconnection with remote tooling.
- Demonstration of a mechanical molten salt line containment isolation valve that remains functional during station blackout conditions.

Questions – Contact: Brian K. Robinson, Brian.Robinson@nuclear.energy.gov

k. Advanced Methods for Manufacturing

A strong manufacturing base is essential to the success of the U.S. reactor designs currently competing in global markets. In addition, the success of the Small Modular Reactor (SMR) Initiative depends heavily on the ability of the U.S. to deliver on the SMR's expected advantages - the capability to manufacture SMRs or subsystems in a factory setting, dramatically reducing the need for costly on-site construction - thereby enabling these smaller designs to be economically competitive and earlier market adoption. A modular fabrication approach is also beneficial to move new or advanced nuclear reactor designs toward commercialization as well as helps to ensure the continued safe, reliable, and economic operation of the existing nuclear fleet.

Modular fabrication of nuclear systems or subsystems can result in reduced costs, fabrication lead times and operational readiness while still maintain the necessary nuclear quality standards. Employing advanced fabrication and manufacturing methods to enable a modular fabrication approach, will require advances in fabrication process integration, robotics/automation, welding processes and inspection methods that can maintain production speed and efficiency within a nuclear quality and regulatory domain.

Applications are sought in the area to enhance modular fabrication in multi-scaled nuclear systems:

Fabrication of multi-scaled nuclear systems or subsystems through modular design features, taking full consideration of current and novel hybrid advanced manufacturing techniques. Proposals should include modular design, fabrication and field integration strategies and implementation of such processes.

Grant applications must be capable of producing components or subcomponents on a limited production basis and with nuclear quality.

Questions - Contact: Dirk Cairns-Gallimore, dirk.cairns-gallimore@nuclear.energy.gov

For more information on the AMM program visit https://www.energy.gov/ne/nuclear-energy-enabling-technologies

l. NSUF SBIR/STTR Workscope

The Nuclear Science User Facilities (NSUF) has strong interest in the development of new and advanced techniques that will enable cutting edge and more cost effective studies related to irradiation effects in nuclear fuels and materials. In addition to increasing the fundamental understanding associated with irradiation effects, NSUF also strives to accelerate both the discovery of new materials that can be applied to the needs of the nuclear industry and the ultimate qualification of those materials. Development of high-throughput characterization techniques are therefore of great relevance. Some of the most important yet most difficult properties to measure with high-throughput methodologies are mechanical properties. Proposals focused on the development of techniques for high-throughput characterization in the area of mechanical property determinations and especially with respect to radioactive materials will be accepted. Of particular interest are techniques for bulk material mechanical properties as well as studies to correlate bulk mechanical properties to those obtained from high-throughput techniques on micro- or nano-scale samples.

Questions - Contact: Tansel Selekler, Tansel.Selekler@nuclear.energy.gov

For more information on the NSUF program visit https://nsuf.inl.gov/

m. Cybersecurity Technologies for Protection of Nuclear Safety, Security, or Emergency Preparedness Systems

The U.S. Department of Energy Office of Nuclear Energy is seeking science and engineering solutions to prevent, detect, and mitigate cyber threats to nuclear energy systems, with specific emphasis on digital instrumentation, control, and communication systems. Proposals of interest will enable nuclear energy system designers, operators and researchers to model/characterize the cybersecurity behaviors and effectiveness of instrumentation and control (I&C) components and systems specific to the nuclear energy sector and/or to mitigate cybersecurity vulnerabilities in such components and systems. Models of most relevance will: 1) simulate the characteristics of a nuclear power plant I&C system under cyber attack; 2) study the cyber risk impacts of upgrades and maintenance on such systems; and/or 3) facilitate nuclear facility operation cybersecurity education and training.

Proposers' product(s) of interest may provide designers, operators, and researchers with capability to:

- Develop and demonstrate cyber secure digital I&C system architectures for use in nuclear facilities across a broad range of current reactors and future reactors, including small modular reactors and microreactors.
- Assess digital I&C systems for their capabilities to: a) minimize common cause cybersecurity failures and common access attacks; b) eliminate various classes of cyber attacks, including cyber attacks that are enabled through the supply chain; and/or c) determine or enhance the resilience of a system to respond and recover from cyber attacks.
- Develop and demonstrate cyber secure wireless technology architectures that enable the use of advanced sensors, actuators, controllers, etc. – architectures that are resilient to cyber-attacks, jamming, and other man-made failure mechanisms.

Proposals not of interest include general cybersecurity solutions for information technology, I&C components and systems or wireless architectures, not specific to the nuclear power sector.

Questions – Contact: Rebecca Onuschak, rebecca.onuschak@nuclear.energy.gov

n. Integrated Energy Systems

Advanced nuclear-renewable integrated energy systems (IES) are composed of one or more nuclear and renewable energy sources, industrial energy users, energy storage systems, and energy conversion systems for electricity production. Various IES configurations are being evaluated for their economic benefit and technical feasibility within multiple geographic regions; systems may be "tightly coupled" within a single "energy park" type of configuration or may be loosely coupled within a grid balancing area.

The Crosscutting Technology Development IES program focuses on the research and development of tools and technologies that will lead to demonstration of multiple integrated energy systems that have a clear path toward commercialization. These demonstrations fall into three categories having different timelines:

~1-5 yrs Current LWR fleet demonstration of IES (electrical and/or thermal integration)

~5-10 yrs Small modular reactor IES demonstration with electrical and/or thermal integration

~5-15 yrs Advanced reactor IES demonstration

The IES program is interested in development and demonstration of technologies that support integration of nuclear-generated thermal energy with non-electric applications. Such technologies may include:

- Advanced sensors (specifically related to the integrated system, not routine nuclear operations) to increase the amount of data available to drive operational decisions, and the associated data management and analysis techniques;
- Smart valves to manage the flow of thermal energy to the coupled energy conversion system, thermal energy storage, or thermal energy user;
- Robust, resilient heat exchangers to effectively and efficiently integrate industrial energy users with nuclear plants;
- Reliable control systems that allow smart, semi-autonomous decision-making on real-time energy dispatch based on signals from the grid operator, real-time renewable energy input and electricity pricing, and operational constraints on the coupled energy systems (e.g. maximum turndown, ramp rates, etc.).

Flexible technologies that can be applied to multiple reactor concepts and multiple energy conversion systems are of interest, but technologies specific to a certain class of reactor (e.g. light water reactor, gas-cooled reactor, etc.), reactor size (e.g. MW-scale, SMR, large-scale), operating temperature range, or power conversion system are also of interest. Limitations to application of the proposed technology should be addressed in the proposal. Proposals that lead to detailed engineering design and deployed experimental hardware in the near term are highly favored; development of computational modeling tools is not desired.

Applicants should not propose a novel reactor or energy conversion system design, but should instead focus on novel coupling technologies, system control, and optimized operational dispatch to support coupled energy applications. Likewise, proposed projects should only involve domestic reactor designs. Cyber-informed engineering should be considered in system design, dispatch optimization, and system control. Systems of interest could be applicable to fixed installations or could be modular and transportable in their design to address a range of applications. Applicants are encouraged to investigate the potential markets and market competitiveness of proposed solutions within large-scale centralized grid or islanded microgrids that may be applicable to SMR or microreactor technologies.

Questions – Contact: Rebecca Onuschak, Rebecca.Onuschak@nuclear.energy.gov

o. Small Modular Reactor Capabilities, Components, and Systems

Improvements and advancements are needed to address capabilities, components, and systems that might be deployed in small modular reactor (SMR) designs, focusing on safe and efficient operations under potentially different pressure and temperature conditions, as well as the need to fit into more confined configurations than might be available in larger designs. The economics of SMRs depend on designing plants that have fewer and smaller components, smaller site footprints, and a reduced amount of operations and maintenance requirements than for reactors in the existing fleet. Concepts that can potentially improve SMR plant capability and performance while reducing capital, construction, operations, and maintenance costs are sought through this work scope. The proposed technology or capability should demonstrate and support improved functionality and efficiencies in SMR plant operation and maintenance processes. Proposed technology improvements can be applicable to any SMR design types (e.g., light water, liquid metal, gas, and molten salt cooled) and to both electrical or non-electrical uses, but should be available on a timeframe to support SMR deployments in the late 2020's and compatible with an SMR design currently under development. Proposals should identify any support function benefits such as in the areas of security, management, administration, procurement, and radiation protection that could result through the implementation of the proposed technology improvement. Due to the limited funding available to support this specific work scope, applications are sought for improvements in the following areas only:

- Compact heat exchangers
- Compact steam generators
- Reactor vessel penetration systems
- Pressure vessel closure mechanisms
- Remote handling capabilities
- Steam isolation systems
- Condenser technologies

Proposals that address the following technology development areas are NOT of interest for this subtopic and will be declined: new small modular reactor design concepts, instrumentation and control capabilities, sensors, remote operations concepts, fuel design & development, and spent fuel storage & handling.

Questions – Contact: Melissa Bates, melissa.bates@nuclear.energy.gov

p. Microreactor Applications and Unattended Operations Technologies

Improvements and advances are needed in support of novel microreactor applications and unattended operations to support wide-spread deployment of these technologies. Microreactors are defined as low power (<20 MW) reactors that are easily transported to and from an application site (such as remote locations) and are based on a range of reactor technologies. Given their size, they are ideal for novel applications that require substantial local power to areas where either there is no grid access or where fuel transportation is challenging or not desired and for other off-grid applications that require highly reliable power or local ownership and control of the power source. There is also a strong desire to minimize the requirement for on-site operators and trained personnel, which will reduce costs and enable wider use of microreactor technology. Therefore, this topic seeks new and innovative concepts and technologies that support the use of microreactor applications in the following areas:

- Civilian applications requiring 100's of kW to MW-scale power in the form of heat or electricity to support remote or non-remote uses. These applications should specifically highlight the need and value of having a reliable source of energy provided by microreactors and have significant potential market opportunities. These concepts should represent the use of the energy, not generation.
- Technologies that support unattended and remote operations of microreactors and minimize on-site highly trained personnel, operators, and maintenance staff. The technologies should not be microreactor design specific but may need to consider the operational characteristics of microreactors.

Proposals that address the following technology development areas are NOT of interest for this subtopic and will be declined: new microreactor concepts, non-civilian applications of microreactors, radioisotope power source applications.

Questions – Contact: Thomas Sowinski, Thomas.Sowinski@nuclear.energy.gov

q. Other

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Won Yoon, Won.Yoon@nuclear.energy.gov

References: Subtopic a, c-q:

1. United States Department of Energy Office of Nuclear Energy, http://energy.gov/ne/office-nuclear-energy

2. United States Department of Energy Office of Nuclear Energy, 2010, Nuclear energy Research and Development Roadmap, Report to Congress https://energy.gov/sites/prod/files/NuclearEnergy_Roadmap_Final.pdf

3. United States Department of Energy Office of Nuclear Energy, Fuel Cycle Research and Development Program, https://energy.gov/ne/fuel-cycle-technologies/fuel-cycle-research-development

4. Idaho National Laboratory, 2010, Technical Program Plan for INL Advanced Reactor Technologies Technical Development Office/Advanced Gas Reactor Fuel Development and Qualification Program, Idaho National Laboratory, Revision 6, INL/MIS-10-20662. https://art.inl.gov/trisofuels/Lists/References/Attachments/44/PLN-3636_rev_6.pdf

5. Petti, D., Bell, G., Gougar, H., 2005, The DOE Advanced Gas Reactor (AGR) Fuel Development and Qualification Program, 2005 International Congress on Advances in Nuclear Power Plants, INEEL/CON-04-02416. https://inis.iaea.org/search/search.aspx?orig_q=RN:39005010

6. Gateway for Accelerated Innovation in Nuclear, 2019, Microreactor Reports and Videos, https://gain.inl.gov/SiteAssets/Micro-ReactorWorkshopPresentations/Micro-ReactorVideoAndReports.pdf

7. Gateway for Accelerated Innovation in Nuclear, 2019, GAIN-EPRI-NEI-US NIC Micro-Reactor Workshop Agenda and Presentations, https://gain.inl.gov/SiteAssets/Forms/AllItems.aspx?RootFolder=/SiteAssets/Micro-ReactorWorkshopPresentations/Presentations&FolderCTID=0x012000556C9CD01B43BF458916A221A352F303&View=%7bE4342CCA-6E12-4688-8297-617F701D2BA2%7d

References: Subtopic b:

1. Idaho National Laboratory, 2013, Overview of the U.S. DOE Accident Tolerant Fuel Development Program, Top Fuel 2013, INL/CON-13-29288, http://www.osti.gov/scitech/servlets/purl/1130553

2. Idaho National Laboratory, 2014, Light Water Reactor Accident Tolerant Fuel Performance Metrics, Advanced Fuels Campaign, INL/EXT-13-29957, http://www.osti.gov/scitech/servlets/purl/1129113

3. Idaho National Laboratory, 2013, Advanced Fuels Campaign 2013 Accomplishments Report, INL/EXT-13-30520, http://www.osti.gov/scitech/servlets/purl/1120800

4. Idaho National Laboratory, 2014, Advanced Fuels Campaign 2014 Accomplishments Report, INL/EXT-14-33515, http://www.osti.gov/scitech/biblio/1169217

5. Idaho National Laboratory Advanced Fuels Home Page, including 2017 Accomplishments Report, https://nuclearfuel.inl.gov/afp/SitePages/Home.aspx

6. Idaho National Laboratory, 2010, Technical Program Plan for INL Advanced Reactor Technologies Technical Development Office/Advanced Gas Reactor Fuel Development and Qualification Program, Rev. 6, INL/MIS-10-20662. https://art.inl.gov/trisofuels/Lists/References/Attachments/44/PLN-3636_rev_6.pdf

7. Petti, D., Bell, G., Gougar, H., 2005, The DOE Advanced Gas Reactor (AGR) Fuel Development and Qualification Program, 2005 International Congress on Advances in Nuclear Power Plants, INEEL/CON-04-02416. https://inis.iaea.org/search/search.aspx?orig_q=RN:39005010

38. ADVANCED TECHNOLOGIES FOR NUCLEAR WASTE

Maximum Phase I Award Amount: $200,000	Maximum Phase II Award Amount: $1,100,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES

The US DOE Office of Nuclear Energy, Office of Spent Fuel and Waste Science and Technology is conducting research in long-term storage, transportation, and eventual disposal of spent nuclear fuel (SNF). Storage of SNF is occurring for longer periods than initially intended; therefore, it is desirable to assess technical performance issues of the SNF storage systems and transportation systems after extended durations. In the area of SNF disposal, research is directed toward generic repository disposal systems in argillite, salt, and crystalline rock.

Grant applications are sought only in the following subtopics:

a. Spent Fuel and Waste Science and Technology, Disposal R&D

Assessments of nuclear waste disposal options start with waste package failure and waste form degradation and consequent mobilization of radionuclides, reactive transport through the near field environment (waste package and engineered barriers), and transport into and through the geosphere. Science, engineering, and technology improvements may advance our understanding of waste isolation in generic deep geologic environments and will facilitate the characterization of the natural system and the design of an effective engineered barrier system for a demonstrable safe total system performance of a disposal system. DOE is required to provide reasonable assurance that the disposal system isolates the waste over long timescales, such that engineered and natural systems work together to prevent or delay migration of waste components to the accessible environment.

Mined geologic repository projects and ongoing generic disposal system investigations generate business and R&D opportunities that focus on current technologies. DOE invites proposals involving novel material development, testing methods, and modeling concept and capability enhancements that support the program efforts to design, develop, and characterize the barrier systems and performance (i.e., to assess the safety of a nuclear waste repository). DOE will also consider proposals addressing applications of state-of-the-art uncertainty quantification and sensitivity analysis approaches to coupled-process modeling and performance assessment which contribute to a better assurance of barrier system performance and the optimization of repository performance.

Research proposals are sought to support the development of materials, modeling tools, and data relevant to permanent disposal of spent nuclear fuel and high-level radioactive waste for a variety of generic mined disposal concepts in clay/shale, salt, crystalline rock, and tuff. Key university research contributions for the disposal portion of this activity may include one or more of the following:

- Improved understanding of waste package failure modes and material degradation processes (i.e. corrosion) for heat generating waste containers/packages considering direct interactions with canister and buffer materials in a repository environment leading to the development of improved models (including uncertainties) to represent the waste container/package long term performance.
- New concepts or approaches for alleviating potential post-closure criticality concerns related to the disposal of high capacity waste packages. Development of models and experimental approaches for including burn-up credit in the assessment of the potential for criticality assessment for spent nuclear fuel permanently disposed in dual- purpose canisters that are designed and licensed for storage and transportation only.
- Development of pertinent data and relevant understanding of aqueous speciation, multiphase barrier interactions, and surface sorption at elevated temperatures and geochemical conditions (e.g., high ionic strength) relevant to deep geologic disposal environments.
- Identification and assessment of innovative and novel buffer materials, new methods and tools for multi-scale integration of flow and transport data, new approaches for characterization of low permeability materials, state-of-the-art tools and methods for passive characterization and monitoring of engineered/natural system component properties and failure modes and their capability to isolate and contain waste.

Questions – Contact: Prasad Nair, Prasad.Nair@nuclear.energy.gov

b. Spent Fuel and Waste Science and Technology, Storage & Transportation R&D

The possibility of stress corrosion cracking (SCC) in welded stainless steel dry storage canisters (DSC) for spent nuclear fuel (SNF) has been identified and studied as a potential safety concern. The welding procedure introduces high tensile residual stresses and changes in material properties in the heat-affected zone (HAZ) of the fabrication welds in the DSC. This welding procedure might promote pitting and SCC crack initiation and growth when exposed to an aggressive chemical environment. Some DSCs are stored in a marine environment, where an aggressive chemical environment might be produced by deliquescence of atmospheric salts, generating an aqueous brine layer on the surface of the canisters. Studies and research conducted so far indicate that the possibility of SCC in these canisters is low and that implementing technologies to mitigate SCC, by reducing the probability of cracks forming or growing, might further reduce the risks for long-term, extended storage of these DSCs. It is envisioned that the technology could be performed on the DSC while it is outside the storage overpack or the transportation cask, (possibly before loading with fuel, before placing in the storage overpack, or during transfer between storage overpack and transportation cask) or, if all the HAZ zones were accessible, while the DSC is inside the storage overpack.

Research proposals are sought to develop mitigation technologies for enhancing the reliability of long-term storage and maintenance of DSCs (as constructed using existing designs). Possible technologies include sprays, coatings, weld depositions, and other techniques where long-term performance can be demonstrated empirically and/or analytically.

Questions – Contact: John Orchard, John.Orchard@doe.gov

[Return to Table of Contents](#)

c. Spent Fuel and Waste Science and Technology, Other R&D

In addition to the specific subtopics listed above, the Department invites grant applications in other areas that fall within the scope of the topic description above.

Questions – Contact: Prasad Nair, Prasad.Nair@nuclear.energy.gov

References:

1. Office of Nuclear Energy, 2017, Used Fuel Disposition R&D Documents, Initiatives, U.S. Department of Energy. https://www.energy.gov/ne/listings/used-fuel-disposition-rd-documents