U.S. Department of Energy

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

Topics

FY 2021

Phase I

Release 2

Version 5, January 8, 2021

- 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:	Monday, November 9, 2020
Funding Opportunity Announcement Issued:	Monday, December 14, 2020
Letter of Intent Due Date:	Monday, January 04, 2021
Application Due Date:	Monday, February 22, 2021
Award Notification Date:	Monday, May 17, 2021*
Start of Grant Budget Period:	Monday, June 28, 2021

*** Date Subject to Change**

Table of Changes		
Version	**Date**	**Change**
Ver. 1	Nov. 09, 2020	Original
Ver. 2	Nov. 19, 2020	• Topic 13, subtopic c: Updated Technical Point of Contact • Topic 20, subtopic c: Updated Technical Point of Contact • Topic 20, subtopic d: Updated Technical Point of Contact • Topic 20, subtopic e: Updated Technical Point of Contact • Office of Nuclear Energy: Updated Program Overview
Ver. 3	Dec. 09, 2020	• Topic 10: Added section for "Assistance with Teaming"
Ver. 4	Dec.15, 2020	• Topic 20, subtopic c: Updated Technical Point of Contact • Topic 20, subtopic d: Updated Technical Point of Contact • Topic 20, subtopic e: Updated Technical Point of Contact
Ver. 5	January 8, 2021	• Topic 12, subtopic d: Updated Subtopic Description

INTRODUCTION TO DOE SBIR/STTR TOPICS

This SBIR/STTR topics document is issued in advance of the FY 2021 DOE SBIR/STTR Phase I Release 2 Funding Opportunity Announcement scheduled to be issued on December 14, 2020. 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.

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 of Defense Nuclear Nonproliferation Research and Development:

4. ARTIFICIAL INTELLIGENCE
    a. Cloud/High-Performance Computing (HPC) Architectures by Design

Office Energy Efficiency and Renewable Energy:

9. ADVANCED MANUFACTURING
    a. Innovation Research in Application Specific Integrated Circuit ASIC Semiconductor Chip Design for Edge Computing in Manufacturing
10. Bioenergy
    b. Cultivating a More Competitive Bioeconomy Through Strengthening Small Business Workforces
13. Joint Topic: Advanced Building Construction Technologies
    d. Advanced Building Construction Digitization Solutions

Office of Fossil Energy:

27. Natural Gas Technologies: Natural Gas Infrastructure
    a. Hydrogen Transport
    b. Sensors for Hydrogen Monitoring
    c. Hydrogen Leakage Detection and Mitigation

Office of Nuclear Energy:

39. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY
    i. Plant Modernization

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 or unique and innovative techniques and methodologies that address a need for the cyber security for the energy sector. 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 and compressor operations in natural gas transmission and distribution. 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. Cybersecurity in Supply Chain and Acquisition

This subtopic is for the development of tools, techniques, and/or methodologies to ensure that concerns for cybersecurity are included in the process of equipment and software acquisition within the energy sector. This proposed solution can include but is not limited to addressing interaction of software and firmware with legacy equipment; addressing interaction of new or updated OT equipment with existing operations; sourcing of Industrial Control System (ICS) equipment subcomponents; and addressing management of a software bill of materials.

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

c. Enhancing Organizational Cybersecurity Awareness

This subtopic is for the development of tools, techniques, and/or methodologies to enhance the operational base for organizational cybersecurity awareness. Proposed solutions can include but are not limited to innovative approaches to enhance awareness of energy sector OT equipment and networking, and distribution; methodologies to include considerations for multiple entities and varying configurations of OT infrastructure in the development of organizational tabletop exercises; addressing organizational awareness of cybersecurity hygiene for OT equipment and networking.

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

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https://www.whitehouse.gov/presidential-actions/executive-order-securing-united-states-bulk-power-system/

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7. IEEE. “C37.240-2014 - IEEE Standard Cybersecurity Requirements for Substation Automation, Protection, and Control Systems.” *IEEE Standards Association*, 2015. https://standards.ieee.org/standard/C37_240-2014.html

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9. North American Transmission Forum. “Bulk Electric Systems Operations Absent Energy Management System and Supervisory Control and Data Acquisition Capabilities—a Spare Tire Approach.” *North American Transmission Forum,* 2017, 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.

These offices seek grant applications in the following topic areas:

2. ALTERNATIVE RADIOLOGICAL SOURCE 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 Office of Proliferation Detection (PD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to reduce the reliance on high-activity commercial and industrial radioactive sources. The office is interested in developing replacements for radiological sources to promote the adoption of non-radioisotopic alternative technologies where technically, operationally, and economically feasible. Grant applications are sought in the following subtopics:

a. Portable Modular Accelerator Technology to Replace Gamma in Irradiation Applications
Ionizing radiation sources are widely used in broad spectrum of applications, including but not limited to: industrial irradiation, cancer treatment, polymer crosslinking, and radiographic inspection of pipes. Multiple irradiation technologies are available: radioisotope sources, non-radioisotopic x-ray sources, and ultrasonic testing sources. The use of high-activity radioisotope sources (including Cs-137, Ir-192, Co-60, and Se-75) poses a radiological security risk since the sources could be stolen and used in a radiological dispersal device, or "dirty bomb". X-ray and electron beam systems have the potential to be used in lieu of radioisotope sources, thus eliminating the security risk. However, for this technology to be widely adopted, additional development is needed to meet end-user requirements for portable, stable operations.

The Office of Proliferation Detection is soliciting the development of a modular and portable irradiation platform capable of replacing the need for radioisotope source-based irradiators in a broad range of applications. The modular device needs to be very mobile and robust to challenging environmental conditions, including varying temperatures. The creation of a standardized platform is desired for both electron and x-ray irradiation. The system should be able to deliver as wide a range in dose as possible within the range of 0.5 Gy/min to hundreds of Gy/min at a wide range of energies from 1 to 10 MeV. The intent is to establish a cost effective common base technology that can be broadly adopted in various applications and industries with minimal additional engineering effort (i.e. shaping electron beam, conversion to x-ray, beam shaping, etc.)

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

b. Glass-metal Fritted Assemblies for Alpha-detection
Glass-metal fritting is a widely used method for several commercial-based applications. However, there is a shortfall in commercial capability for specialized detector fabrication for some nonproliferation needs, such as alpha detection in associated particle neutron generators. The Office of Proliferation Detection requires a reliably produced source for hermetic glass-metal assemblies that consists of a fiber-optic window with a viewable diameter greater than or equal to 50 mm. Complexities of manufacturing include sealing the assembly to a flange that can be welded into a stainless steel housing and baked at 300° C for an extended (> 1 day) period without loss of vacuum seal. The fiber-optic window must be compatible with the use of extra-mural absorption (EMA) fibers to absorb stray photons not contained within individual fibers, have a numerical aperture of at least 0.6, and a leak rate less than 1e-10 std cc/s. Existing NNSA projects have identified he opportunity to establish this specialized fabrication capability. Please contact the topic POC for more information.

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

References: Subtopic a:

1. National Research Council. "Radiation Source Use and Replacement: Abbreviated Version." National Academies Press, 2008, https://www.nap.edu/catalog/11976/radiation-source-use-and-replacement-abbreviated-version

2. U.S. Department of Energy. "Basic Research Needs Workshop on Compact Accelerators for Security and Medicine." U.S. Department of Energy, Office of Science, 2019, https://science.osti.gov/-/media/hep/pdf/Reports/2020/CASM_WorkshopReport.pdf?la=en&hash=AEB0B318ED0436B1C5FF4EE0FDD6DEB84C2F15B2

3. REMOTE DETECTION 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 Remote Detection Program within the Office of Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to develop new technologies and methods for nuclear and radiological material security. Meeting this objective requires the improvement of current technology and the development of new tools for remote detection applications. These advances can be used to enable emergency response, safeguards, treaty verification, and other government applications. Research areas in the remote sensing program include: 1) the development of imaging and non-imaging systems (passive or active), 2) multi-modal detection technology, and 3) enhancing detection opportunities through computational methods. Grant applications are sought in the following subtopics:

a. Extending Remote Gas Sensing Range

Fast spectral identification of multiple chemical species is essential when signals are short lived or in constant flux. In response to this, a variety of active sensing systems have been investigated in the past. For example, frequency comb technologies have been shown to provide large spectral coverage while maintaining high resolution [1].

Proposed efforts under this topic should seek to extend the range of sensing systems that can identify multiple gaseous species beyond 1km distance-to-target [2]. High priority should be given to the maximization of signal-to-noise ratios.

Questions – Contact: Chris Ramos, Christopher.ramos@nnsa.doe.gov

b. Networked Edge Sensing

Advances in neuromorphic engineering [1] and event-based sensing have demonstrated new paradigms for remote sensing science. This is in part due to increased computation and analysis on-board the sensor (or 'at the edge'). Additionally, these technologies are capable of reduced size, weight, and power requirements.

Proposed efforts under this topic should investigate the networking of edge sensing sensors to enhance persistence, increase range, or minimize noise. Modalities that are of interest include: EM, optical, or seismo-acoustic.

Questions – Contact: Chris Ramos, Christopher.ramos@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: Chris Ramos, Christopher.ramos@nnsa.doe.gov

References: Subtopic a:

1. Kowligy, A., et al. "Infrared electric field sampled frequency comb spectroscopy." *Science Advances,* 7 June 2019, https://advances.sciencemag.org/content/advances/5/6/eaaw8794.full.pdf

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1. Posch, C. "Bio-inspired vision." *Journal of Instrumentation, Volume 7*, January 2012, https://iopscience.iop.org/article/10.1088/1748-0221/7/01/C01054

2. Leng, S., Posch, C., et al. "Asynchronous Neuromorphic Event-Driven Image Filtering", *Vol. 102, No. 10*, October 2014 | Proceedings of the IEEE, https://www.neuromorphic-vision.com/public/publications/20/publication.pdf

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4. ARTIFICIAL INTELLIGENCE

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 and demonstrate innovative, digital methods to accelerate the transition of the next generation of Artificial Intelligence (AI) technologies. COTS AI is generally inadequate for the highly-specialized, high-consequence mission of the national security domain. Meeting this objective requires innovation in data science and AI capabilities to broadly enhance DNN R&D's diverse capabilities in feature engineering and detection, remote sensing, and signal processing capabilities. Grant applications are sought in the following subtopic:

a. Cloud/High-Performance Computing (HPC) Architectures by Design

Innovation in cost-effective cloud/high-performance computing (HPC) architectures by design is needed to enhance traditional capabilities in remote sensing and signal processing capabilities and enable non-traditional methods (e.g., machine learning) for feature engineering and detection. There is a growing opportunity for expanded mission capability through the utilization of increasingly-available public and commercial imagery and sensor data, as well as open-source text streams, including social media, newsfeeds, scientific literature, and public records. There is also a growing number of HPC-based system models (deterministic and optimization-based) that need to be cost-effectively integrated with data analytics through cost- and time-optimized cloud/HPC architectures. Successful proposals will develop a system concept and software architecture for a proposed cloud and HPC combined architecture that optimizes cost-to-solution and time-to-solution, and should include at least two diverse data streams and one HPC-based systems model for demonstration of a limited-functionality prototype. Phase I deliverable is a final report that describes system concept, software architecture, algorithms, and results from limited functionality prototype demonstration.

Questions – Contact: Angie Sheffield, angela.sheffield@nnsa.doe.gov

b. Other

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

Questions – Contact: Angie Sheffield, angela.sheffield@nnsa.doe.gov

5. DIGITIZING AND ANALYZING LEGACY SEISMO-ACOUSTIC DATA

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

Legacy recordings of seismic or infrasonic/acoustic events, including past nuclear tests, are of interest to the community, but many are hard to analyze because they exist only as paper records of analog waveforms, analog media (e.g., Ampex tapes), or digitized data on obsolete storage media (e.g., Digital Audio Tape (DAT), 9-track, or removable discs) that no longer have readily available readers. There is an analogous need to digitize similar types of analog data in satellite telemetry (also with Ampex tapes) and medical records (e.g., electrocardiograms), as part of acquiring a broader base of information for historical recordkeeping and research purposes.

Threats to the loss of information in legacy analog and digital recordings include the degradation of the physical media and the large physical space required to store the records. Cataloging and scanning the analog data are a way to triage and preserve the data, but this is only the first step of a path toward a scientifically useful product. Grant applications are sought in the following areas:

a. Digitization of Legacy Seismo-acoustic Waveform Data

Research is needed to improve the robustness and automation of techniques to rapidly and accurately digitize analog records of legacy seismo-acoustic waveform data. Scanning records has limitations in the tradeoff between scanning time vs. resolution. A variety of original recording technologies (e.g., paper helicorders, film develocorders), each with associated idiosyncrasies, generated data that must be recovered [1, 2, 3, 4]. Of interest are methods that streamline the scanning and digitization process, ideally allowing for treatment of a variety of original data types and correcting for complications such as overlapping signals, rotating drum distortions, and time marks. The resulting techniques would enhance legacy data digitization by enabling automated translation of historical data into a useable form. Digitizations of interest include signal and noise spectra at frequencies from approximately 0.02 to 20 Hz and timing precision that can be quantified.

Questions – Contact: Thomas Kiess, thomas.kiess@nnsa.doe.gov

b. Methods to Readily Read, Recover, and Organize Legacy Digital Storage Media

Research is needed to develop methods to readily read, recover, and organize data from legacy digital storage media (e.g., DAT, 9-track, etc.) before these media degrade and become unreadable [1, 2]. Information of interest includes file formats, as well as sensor and catalog metadata. Metadata includes operational time period and site information, as well as full digital data recovery. Particular attention is needed for reading aging media (physically and magnetically weak), including the possibility that media may break and degrade beyond usability after a few read cycles [3, 4].

Questions – Contact: Thomas Kiess, thomas.kiess@nnsa.doe.gov

c. Analysis Methods to Identify the Instrument Response Function (IRF) for De-convolution

The recorded trace on a seismometer is the incident ground motion convolved with the response function of the sensor and data acquisition system. It is necessary to remove the response function from the data in order to obtain the true measured time history of ground motion. Methods of removing the response function exist if it is known [1, 2]. However, for a signal recorded from a legacy instrument, the amplitude and phase response of the instrument may not have been preserved. Many of these legacy instruments no longer exist and records of calibrations performed during their lifetime may be missing or incomplete.

The challenge is to conduct research to devise methods of analyzing the waveform time series represented in the legacy data to estimate the sensor and data acquisition instrument response function (IRF). The frequency passband required for seismic waveform analysis is primarily over the operational monitoring band of 0.02 to 20 Hz, but also of interest are methods applicable at lower frequencies down to 0.0083 Hz (120-second periods). Possible approaches can include, but not limited to, analysis of the microseism and other background noise [3], analysis of recorded events in the historical archive with known signal characteristics (such as large magnitude earthquakes), and comparison of the legacy IRF to other nearby seismometers with known response functions that may have been operating during overlapping time periods.

A potential approach is to develop a signal analysis algorithm to identify the amplitude of the first and subsequent peaks, and to derive the uncertainty in these values, given an IRF and a noise spectrum model, or in a self-consistent analysis in which the full trace constrains how significant the IRF and noise are in modifying the size of the largest peaks and features. An outcome of interest is to generate such a self-consistent analysis from a legacy recording trace, and deduce limits on how much influence the IRF or noise would have on the amplitude of the major peaks (primarily the first one), to produce the "true amplitude" and its uncertainty. There might be analogous applications in medical record analyses (e.g., elucidating relative size of s- vs. t- waves vs. other elements of electrocardiogram traces) [4].

Questions – Contact: Thomas Kiess, thomas.kiess@nnsa.doe.gov

d. Other

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

Questions – Contact: Thomas Kiess, thomas.kiess@nnsa.doe.gov

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6. SURFACE MAPPING MICROANALYSIS

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

Nuclear forensics analysis often involves combining information from several microanalytical imaging technologies (e.g., optical microscopy, scanning electron microscopy [SEM], secondary ion mass spectrometry [SIMS], and other spectroscopic methods) in a serial fashion to provide a complete characterization of material samples. A significant challenge for analytical imaging technologies is the characterization of a single region of interest by complementary methods, which requires precise sample positioning, identification of features that warrant analysis by different analytical techniques, relocation of regions or features with high accuracy (typically within a few micrometers) on different analytical platforms, correlation of analytical signals from disparate technologies (e.g., reflected light, secondary electrons or ions, x-ray fluorescence, etc.), and visualization (e.g., 2-D or 3-D surface mapping). Therefore, of interest to DNN R&D are innovative solutions to (i) rapidly scan surfaces using various microscopies, (ii) efficiently correlate microanalytical images that provide complementary information, (iii) combine images so that they correctly align, and (iv) enable 2-D and 3-D surface mapping that combine disparate analytical data. Regions of interest can require cross-platform spatial resolution of one micrometer or less. For example, features of interest can be identified by rapid scanning using one or more imaging techniques (e.g. optical, SEM, SIMS, etc.); regions are relocated on a separation analytical platform for further analysis at short length scales; disparate information streams (e.g., chemical, elemental, isotopic, morphologic) are correlated to align or overlay features at high spatial resolution; and finally, optical images are then utilized to develop a 2-D or 3-D surface map combining all analytical information. Research is needed to achieve rapid scanning and spatial alignment of surface maps made by each microscopy to the same x-y-z position. Materials of interest may be affixed to sample holding substrates made of various materials (e.g., glass, carbon, plastic, silicon, gold, aluminum, or steel). Thermal stability, electrical conductivity, material compatibility, and stability all must be maintained, such that regions of interest can be archived and reanalyzed as needed. Approaches should enable the ability to identify and target key features, to include but not limited to: trace surface contamination, particle grain inclusions, surface treatments, signs of aging or corrosion, and radiolytic damage.

Grant applications are sought in the following subtopics:

a. Rapid Scanning and Feature Discrimination

Research in rapid scanning of SNM surfaces is needed to image and identify down to sub-micron resolution unusual features (e.g., defects, areas of anomalous composition, or material inclusions) on samples of special nuclear material (SNM) or surrogates (e.g., cerium oxide or depleted uranium samples). Technology developed in this subtopic is of value to either (i) enable scans of surfaces (ideally 1 sq. cm area) using various microscopies (electron, optical, other) at high resolution (ideally micron or sub-micron resolution) rapidly (ideally hours or days rather than years to complete a high-resolution scan of such a large surface area), or (ii) enable scans of surfaces (ideally 1 sq. cm area) using various microscopies (electron, optical, other) at relatively low resolution rapidly, then apply algorithms to select subsample spots for micron-scale imaging. Software algorithms developed in this subtopic could be used to locate micron-sized particles of interest (e.g., dust or pollen grains) or regions of abnormality for further scrutiny and analysis. This subtopic welcomes rapid approaches that facilitate the determination of whether a single mapped square cm area is truly representative of the entire sample surface, as well as probe whether a subsample image exhibits correlated pattern templates representing the full area under investigation.

Questions – Contact: Timothy Ashenfelter, Timothy.Ashenfelter@nnsa.doe.gov

b. 2-D and 3-D Surface Mapping Across Multiple Microscopy Platforms

Research is needed in machine vision approaches that correlate features in the spatial fields-of-view between optical microscopy platforms and analytical images obtained by other means such as SEM, SEM-Energy Dispersive Spectrometry (EDS), and SIMS. Software algorithms and/or instrumentation developed in this subtopic is of value to enable (i) scans of surfaces using various microscopies (e.g., electron or optical), (ii) image correlation to align and overlay images from combinations of imaging platforms, (iii) accurate indexing of features of interest on microscopy platforms to resolutions of 1 micrometer or better, and/or (iv) 3-D mapping of surface topography to assess surface uniformity as a function of position. Sample substrates typically require conductive materials such as metal-coated glass, silicon, or carbon and require registration at or better than the one-micrometer scale. Techniques are desired to assess surface uniformity, curvature, or address morphology as a function of position, for optically rough surfaces of the order of one square centimeter.

Questions – Contact: Timothy Ashenfelter, Timothy.Ashenfelter@nnsa.doe.gov

c. Spatial Alignment and Target Extraction

Research is needed to develop an optical inspection and robust sample manipulation stage for the removal of particulates of typical diameter 1-300 micrometers from an oxide or metal surface. The functionality of interest is that of a stage of an optical microscope, with manipulation capable of at least four degrees of freedom (DOF) – e.g., x, y, z sample movement and z movement of a particle removal mechanism – with sub-micrometer reproducible positioning. In our application, sample removal mechanisms must utilize methods that do not alter the chemical composition of the particulates or transfer contamination so that ultra-trace destructive analyses can be performed to characterize the chemical and isotopic composition of collected particles. Materials of interest are solid samples comprised of both refractory materials (e.g., SiO_2, Al_2O_3, and similar oxides) and light elements (i.e., low-Z organic macromolecules). Also of interest are techniques that provide a 3-D visualization of the extracted component.

Questions – Contact: Timothy Ashenfelter, Timothy.Ashenfelter@nnsa.doe.gov

Return to Table of Contents

d. Other

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

Questions – Contact: Timothy Ashenfelter, Timothy.Ashenfelter@nnsa.doe.gov

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Return to Table of Contents

PROGRAM AREA OVERVIEW: OFFICE OF ELECTRICITY

The Office of Electricity (OE) leads the Department of Energy's efforts to ensure that the Nation's energy delivery system is secure, resilient, and reliable. Working closely with public and private partners funds the development of new technologies that enhance the infrastructure that delivers electricity at the transmission and distribution levels across North America. OE has taken deliberate efforts to ensure the nation's most critical energy infrastructure is secure and able to recover rapidly from disruptions.

OE recognizes that our Nation's sustained economic prosperity, quality of life, and global competitiveness depend on access to an abundance of secure, reliable, and affordable energy resources. The mission of OE is to drive electric grid modernization and resiliency in the energy infrastructure. Through a mix of technology and policy solutions, OE will address the changing dynamics and uncertainties in which the electric system will operate. OE leverages effective partnerships, solid research, and best practices to address diverse interests in achieving economic, societal, and environmental objectives.

OE has a broad portfolio of activities that spans technology innovation, institutional support and alignment, and security and resilience. Serving 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.

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.

7. 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 increasing stress due to fundamental changes in both supply-side and demand-side technologies. On the supply-side, there is a shift from large synchronous generators to smaller, lighter units (e.g., gas-fired turbines) and variable energy resources (e.g., renewables) with utility scale energy storage. On the demand-side, there is a growing number of distributed energy resources, as well as a shift from large induction motors to rapidly increasing use of electronic converters in buildings, industrial equipment, and consumer devices. The monitoring and control systems used for 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.

Grid modernization will require the adoption of advanced technologies, such as smart meters, automated feeder switches, fiber optic and wireless networks, energy storage, and other new hardware. It must also encompass and enable the application of intelligent devices, next-generation components, cybersecurity protections, advanced grid modeling and applications, distributed energy resources, and innovative architectures. Integration of these technologies will require a new communication and control layer to manage a changing mix of supply- and demand-side resources, evolving threats, and to provide new services.

The transition to a modern grid will create new technical challenges for an electric power system that was not designed for today's requirements. Customers have never relied more on electricity, nor been so involved in where and how it is generated, stored, and used. Utilities will continue retrofitting the existing infrastructure with a variety of smart digital devices and communication technologies needed to enable the distributed, two-way flow of information and energy. Reliability, resilience, and security will remain a top priority as aging infrastructure and changing demand, supply, and market structures create new operational challenges.

All applications to 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. Advanced Protective Relaying Technologies and Tools

The reliability of an electric transmission or distribution system in response to a fault is heavily dependent upon the underlying protection scheme that is being utilized to identify and respond to that fault. The equipment that forms the basis of these schemes include:

- Protective relays which respond to electrical quantities,
- Communications systems necessary for correct operation of protective functions,
- Voltage and current sensing devices providing inputs to protective relays,
- Station dc supply associated with protective functions (including station batteries, battery chargers, and non-battery-based dc supply), and
- Control circuitry associated with protective functions through the trip coil(s) of the circuit breakers or other interrupting devices.

Innovative advancements in protective relaying systems are almost limitless, which is why this topic area is focused more on reducing or eliminating those aspects that inhibit the performance and reliability of the elements in this field while improving the resiliency of such elements. Examples of such innovation include but are not limited to: Dynamic, adaptive or setting-less relays; Distinguishing between momentary and permanent faults; Misoperation reduction; and hidden failures. Collaboration with protection device manufacturers and utility protection engineers is strongly encouraged.

Questions – Contact: David Howard, david.howard@hq.doe.gov

b. New Methods for Training Operators Leveraging Advances in Cognitive Science

As the grid has evolved, it has continued to become increasingly complex. At the same time, our reliance on electricity has grown and tolerance for power interruptions have decreased. This means that new operators are entering into an increasingly demanding environment – and may not have much time to learn through trial and experience on the job. 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. Understanding what system operators require to make informed decisions and analysis, human factors innovation in visualization and decision making can enable more effective training for new operators. Training methods that are able to help the operator learn the uniqueness of the system they will be operating, as opposed to a generic power systems, are needed to meet the growing complexity of the system.

Applications to this subtopic should consider:

- State of the art of human factors and cognitive science 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 training given electricity system interdependences with other sectors (such as natural gas).

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

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

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8. ADVANCED POWER CONVERSION SYSTEM MAGNETICS FOR GRID-TIED 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: NO

The widespread adoption of grid-tied energy storage systems continues to grow, especially due to increasing deployment of renewable energy such as photovoltaic and wind energy systems. Grid-tied energy storage systems add valuable functionality such as renewable firming, frequency regulation, power quality enhancement, and dynamic stability support. Grid storage will ultimately improve the reliability, flexibility, security, and quality of the existing electricity utility grid. The enabling technology that is crucial to these applications is the power conversion system (PCS). The power conversion system controls the power supplied and absorbed from the grid to energy storage device performance while maintaining grid stability. Critical electrical components used in PCS are semiconductors, magnetics such as transformers and inductors, and capacitors. With the advances in wide bandgap semiconductor devices such as SiC and GaN, new topologies for PCSs are emerging due to their high switching frequency, high junction temperature, and high breakdown voltage capabilities. There is increased interest in the usage of high-frequency link converters by utilizing dual active bridge technology. This approach can significantly reduce the size of the transformer while providing galvanic isolation.

All applications to 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 subtopic:

a. Advanced Manufactured High Frequency Link Transformers for Next Generation Grid-tied Energy Storage Power Conversion Systems

To date, energy storage systems employ line frequency transformers for voltage matching at the point of common coupling and galvanic isolation. However, these transformers can have a large footprint, lossy, noisy, and heavy, which can limit high density power conversion designs. Recently, there has been interest in high-frequency link converters to reduce the size of the transformer. The magnetic cores utilized in such systems are critical for proper operation and when paired with wide bandgap semiconductors can become the bottleneck for high power throughput, particularly given the limitations of the current available materials. Additionally, even with the significantly lower inductance requirements at high frequency, the current materials demand that the transformer take up a disproportionately large piece of the power electronics footprint (especially if the power electronics design dictates that they be passively cooled) and cost. Added flexibility and agility in PCS design and deployment could be realized through advanced manufactured transformer and inductor cores. Additively manufactured (AM) or 3D printed cores could be fabricated directly onto printed circuit boards (PCBs) and eliminate pick and place power electronics assembly. Manufacturing could be further streamlined through the additive manufacture of the windings in addition to the magnetic core. Applications are sought to demonstrate an additively manufactured high frequency (≥ 100 kHz) transformer (complete with AM windings) for dual active bridge converter topology rated at

> 10 kW, 48 Vdc input and > 300 Vdc output to ultimately further the power density of next generation 3-phase 480/208 Vac PCS. The transformer should be capable of operating at temperatures of ≥ 150 °C. The final design should show a significant increase in performance, cost reduction, and decrease in footprint compared to a traditional grid-tied power conversion design connected to line frequency transformer.

Questions – Contact: Imre Gyuk, imre.gyuk@hq.doe.gov

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3. Plotkowski, A., Carver, K., List, F., Pries, J., Li, Z., Rossy, A.M., Leonard, D. "Design and performance of an additively manufactured high-Si transformer core." *Materials & Design* 194, 108894, 2020, https://www.sciencedirect.com/science/article/pii/S0264127520304287

4. Simpson, N., Tighe, C., Mellor, P. "Design of High Performance Shaped Profile Windings for Additive Manufacture." *2019 IEEE Energy Conversion Congress and Exposition (ECCE)*, pp. 761-768, 2019, https://ieeexplore.ieee.org/document/8912923

5. Simpson, N., Mellor, P.H. "Additive manufacturing of shaped profile windings for minimal AC loss in gapped inductors." *2017 IEEE International Electric Machines and Drives Conference (IEMDC)*, pp. 1-7, 2017, https://www.semanticscholar.org/paper/Additive-manufacturing-of-shaped-profile-windings-Simpson-Mellor/192a279593cc3d18b7239d7ce70cf92dc996206d

PROGRAM AREA OVERVIEW: OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

The Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) invests in research and development (R&D) as part of the Department of Energy's (DOE) broad portfolio approach to addressing our Nation's energy and environmental challenges.

EERE supports transformative science and emerging energy technologies in energy efficiency, renewable power, and sustainable transportation. Knowledge generated by EERE R&D enables U.S. industries, businesses, and entrepreneurs to develop and deploy innovative energy technologies and gives them the competitive edge needed to excel in the rapidly changing global energy economy. Industry deployment of these technologies creates jobs, increases energy affordability, improves energy security and resilience, ensures environmental responsibility, and offers Americans a broader range of energy choices.

In FY 2021, EERE is prioritizing support for small business research activities in support of DOE-wide crosscutting activities and other Administration priorities, including activities in support of enabling the Industries of the Future (IoTF) to support this goal along with other high-priority research areas across its technology portfolio. Through this multidisciplinary focus, EERE hopes to foster synergies across its technology focuses and develop innovative energy solutions. Please note that each topic and subtopics may have unique requirements for responsive proposal submissions; review the requirements for each topic and subtopic carefully to ensure you are responsive to requirements where applicable.

Commercialization Assistance and the American-Made Network

Applicants are encouraged to take advantage of the Commercialization Assistance Program, which provides funding for commercialization activities in addition to SBIR/STTR research funding. Please read all sections of this FOA with more information about this program and how to apply for this additional funding opportunity.

The American-Made Network is a great resource for finding commercialization-assistance providers and vendors with specific expertise across EERE's technology sectors. The Network helps accelerate innovations through a diverse and powerful group of entities that includes National Laboratories, energy incubators, investors, prototyping and testing facilities, and other industry partners from across the United States who engage, connect, mentor, and amplify the efforts of small businesses. The Network can help companies solve pressing technology challenges, forge connections, and advance potentially game-changing ideas and innovations.

9. 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

EERE's Advanced Manufacturing Office (AMO) (http://energy.gov/eere/amo) collaborates with industry, small business, universities, national laboratories and other stakeholders on emerging manufacturing technologies to drive U.S. energy productivity and economic competitiveness. AMO has a dual mission to develop technologies that reduce manufacturing energy intensity and/or reduce the life cycle energy impact of manufactured goods.

This Topic reflects DOE's support for Advanced Manufacturing Research and Development (R&D) as part of its funding to advance the Industries of the Future. It includes activities that develop new paradigms, methods, processes, or equipment for new or existing manufacturing products, materials, or supply chain components and that provide an advantage over existing techniques or tools. Advantages include reduced time to market, enabling new performance attributes, improving small-batch production, cost savings, energy savings, or reduced environmental impact from the manufacturing of products.

All proposals to this topic must:

- Propose a tightly structured program which includes clear, manufacturing-relevant technical milestones/timeline that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Provide evidence that the proposer has relevant manufacturing experience and capability;
- Clearly define metrics and expected deliverables;
- Explain applications of project output and potential for future commercialization;
- 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;
- Include an energy savings impact and impact grid 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.

NOTE: In addition to the subtopics below, AMO is considering funding proposals in response to the following three multi-office topics: Topic 20 – Joint Topic: CABLE Materials And Applications; Topic 11 – Joint Topic: Polymers Upcycling and Recycling; and Topic 13 – Joint Topic: Advanced Building Construction Technologies.

Applications must be responsive to the following subtopics. Applications outside of these subtopic areas will not be considered.

a. Innovation Research in Application Specific Integrated Circuit ASIC Semiconductor Chip Design for Edge Computing in Manufacturing

The objective of this subtopic is to maintain US manufacturing leadership by providing small business opportunities to develop technologies that will be applied in next-generation manufacturing [1]. Small businesses that provide applied Artificial Intelligence (AI) semiconductor technology design and concept development are afforded the opportunity to work with US semiconductor fabricators to bring AI technology that will rely on 5G broadband wireless communications to applications in the US manufacturing sector [2]. Many technologies that are presently applied in manufacturing process control, for example, that rely on wired communication links, will be superseded by wireless communications, and adaptive control approaches based on AI and machine learning strategies will be possible with the digital computing power that will be accessible with 5G broadband wireless communications.

This subtopic solicits feasibility research in new application-specific integrated circuit (ASIC) designs that will enable AI application in edge computing applications such as automatic control. This subtopic reflects DOE's support for to enable 5G/Advanced Wireless Technologies as part of its focus on enabling the Industries of the Future as well as DOE\EERE's support for Advanced Microelectronics.

The introduction of 5G broadband wireless communications will enable manufacturers to access resources available only with 5G wireless – such as cloud computing and complex wireless sensor networks. This broadband access, in turn, will facilitate the application of digital computing at points of access or presence in manufacturing operations (edge computing). This includes AI applications in automatic control of discrete and continuous processes. Open and closed loop control in manufacturing requires sensing of process or operation variables and the application of algorithms by controllers to act on sensor measurements to control final elements in control loops. AI-based control approaches derive algorithms for closed loop control and models for open loop control using a variety of machine learning approaches to analyze data.

ASIC designs developed for this subtopic are expected to be 5G compatible and be of direct use in edge computing applied to US manufacturing, such as applications in automatic control. Small businesses providing promising new ASIC designs would be expected to work with semiconductor circuit manufactures to fabricate the new ASIC and integrate these into edge computing systems that would be used by manufacturers, with a specified purpose such as automatic control of processes and operations. Grant applications responsive to this Phase 1 funding opportunity will specify the proposed end use in US manufacturing of new ASIC designs, the AI and machine learning approaches to be applied by the ASIC, the possible integration of the ASIC into an edge computing system, and discuss the benefits of the possible new technology as compared with current manufacturing practice in the US.

Questions – Contact: Brian Valentine, Brian.Valentine@ee.doe.gov

b. Novel Manufacturing Methods for Membranes and Desalination System Components

This subtopic solicits proposals to develop continuous, precise, and smart manufacturing techniques that have the potential to lower the cost and facilitate the adoption of high-performance membrane materials and design architectures. Together, such changes in design and materials manufacturing methods could substantially reduce the time to market for new membranes critical for desalination of water. Novel manufacturing methods must be explored to ensure new materials for membranes and desalination systems can be produced with suitable low-cost and scalability. Therefore, the R&D supported under this subtopic must improve materials, design, and manufacturability of high-performance membranes and desalination system components with the goal of reducing costs relative to current methods.

This subtopic supports the objectives of the Water Security Grand Challenge, a DOE-led framework to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water [1].

Proposals must address one of the following three areas of interest to be considered responsive to this subtopic:

1. Low-cost membrane materials and manufacturing methods: R&D is needed to advance the next generation of membrane materials and manufacturing methods. Researchers developing new membrane materials must balance material performance (e.g., separation properties, thermal conductivity, catalytic activity), against robustness (e.g., mechanical, chemical) and manufacturability (e.g., cost, scalability). Materials R&D can lead to improvements in surface chemistry and interfaces that enable development of materials having 1) high-target ion selectivity, 2) high contaminant removal and water permeability, and 3) greater chemical resistance, antifouling and corrosion-resistance compared to state of the art. Innovations in both membrane materials and related manufacturing methods could vastly expand the range of water chemistries over which modular membrane systems are cost-competitive and potentially eliminate the need for energy-intensive pretreatment and post-treatment.

Innovations in high-performance materials and multifunctional membranes enabled by new approaches in materials discovery, synthesis, and characterization are sought. Novel methods of manufacturing that lower cost and improve chemical and hydrodynamic performance that could substantially lower the energy intensity, levelized cost of water (LCOW), water intensity, and failure frequency of treatment processes to increase the nation's ability to tap nontraditional water sources also are sought. Such materials for membranes may become more cost effective if they can leverage recent additive, gradient, and roll-to-roll manufacturing advances that lower production costs.

2. Manufacturing ultra-low cost, high sensitivity sensors and sensor networks for water quality measurements and detection of emerging contaminants: Current water treatment systems are designed to operate at nominally steady-state conditions, relying on human intervention to adapt to variations in water quality and correct failures in process performance. Simple, robust sensor networks coupled with sophisticated analytics and controls systems could enhance performance efficiency, process reliability, and treatment process adaptability while minimizing the need for onsite, manual interventions. These innovations could significantly lower the cost of distributed, fit-for-purpose desalination systems and their operational expenses, thus reducing the overall cost of water treatment This area of interest is focused on developing new, innovative sensors and overcoming related manufacturability challenges for high sensitivity sensors and sensor networks for water quality measurements and detection of emerging contaminants. These sensor data could be used to optimize desalination and other water treatment processes. Data needs for process control and monitoring could also be addressed through these new sensors and sensor networks.

3. Novel methods and technologies for in-situ characterization of membranes during roll-to-roll or otherwise continuous manufacturing: Traditional manufacturing methods can hinder the adoption of novel materials and new architectural designs in desalination system components such as membranes. To reduce membrane costs, there is a need to develop roll-to-roll (R2R) platforms and other continuous manufacturing processes that allow careful control of membrane microstructure and performance. For example, development of new ceramic and composite materials could be accelerated to commercial scale with research on additive and R2R manufacturing, enabled by development of methods to deposit ceramics on complex shapes and rough surfaces. These advances require the development of 1) in-situ characterization techniques that enable control of membrane properties during manufacturing; 2) in operando materials characterization techniques that facilitate understanding of membrane performance under varying conditions; and 3) manufacturing innovations that enable the scalable deployment of novel membrane materials in cost-competitive modules. Process optimization could be achieved by advanced characterization capabilities, such as in-situ X-ray scattering during R2R processing. Cutting-edge characterization tools at national user facilities could be leveraged for materials and processes design and optimization of membrane manufacturing.

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

References: Subtopic a:

1. Semiconductor Industry Association. "New SIA Report Highlights Industry's Strength and Looming Challenges." *Report on the State of US semiconductor industry*, June 18, 2020, https://www.semiconductors.org/new-sia-report-highlights-industrys-strength-and-looming-challenges/

2. McEllan, P. "AI Drives A New Wave For Semiconductors." *Semiconductor Engineering,* June 4, 2020 https://semiengineering.com/ai-drives-a-new-wave-for-semiconductors/

References: Subtopic b:

1. U.S. Department of Energy. "About the Water Security Grand Challenge." US DOE, 2020, https://www.energy.gov/water-security-grand-challenge/water-security-grand-challenge

10. 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. In FY 2021, BETO is focusing on broadening participation-related topics (see below).

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; and
- Be based on sound scientific principles (i.e. abides by the law of thermodynamics).

Grant applications are sought only in the following subtopics. Please note that while proposals are being requested in these subtopics, distribution of awards across these subtopics will be based on the quantity and quality of proposals received.

Assistance with Teaming

Applications that include representation from diverse entities such as, but not limited to: Minority Serving Institutions (MSIs), including Historically Black Colleges and Universities (HBCUs)/Other Minority Institutions (OMIs) [1], or through linkages with Opportunity Zones [2], are encouraged. In addition to bioenergy small businesses, local-level organizations and STEM and R&D consultancies that qualify as for-profit small businesses may also be able to apply or benefit from participation in either of these topics. Proposals can include teams with other than small businesses like universities and non-profits, please review eligibility requirements for further guidance [3].

BETO is compiling a Partners List to facilitate the widest possible national participation in the formation of teams for this topic. The list allows organizations who may wish to participate in an application to express their interest to potential applicants and to explore potential partners.

The Partners List will be available on the BETO's website at https://www.energy.gov/eere/bioenergy/broadening-participation-bioeconomy-through-small-business-partnerships during the time of the FOA release through its closing. The Partners List will be updated at least weekly until the close of the Full Application period, to reflect new Partners who have provided their information. Any organization that would like to be included on this list should submit the following information to bioeconomy@ee.doe.gov, with the subject line "SBIR Partnering Information":

Topic Area(s) of Interest (10A or 10B), Organization Name, Organization Location (City, State), Contact Name, Contact Email, Organization Type, Area of Technical Expertise (bulleted list, no more than 25 words), and Brief Description of Capabilities (no more than 100 words).

An organization that would like to be listed as an interested partner for both 10a and 10b should submit separate Partners List entries. By submitting a request to be included on the Partners List, the requesting organization consents to the publication of the above-referenced information. By facilitating this Partners List, the Department of Energy does not endorse or evaluate the qualifications of the entities that self-identify themselves for placement on the Partners List. The Department of Energy will neither pay for the provision of any of the above-referenced information, nor will it compensate any applicants or requesting organizations for the development of such information. The nature of any possible partner relationship: (1) is determined by the parties of the relationship, not DOE, and (2) may be terminated at any time, subject to any terms and conditions of a SBIR or STTR award.

Note: In addition to the subtopics below, BETO is considering proposals in response to Topic 11 - Joint Topic: Polymers Upcycling and Recycling.

a. Small Business Bioenergy Technologies Increasing Community Partnerships

This subtopic encourages submission of innovative research proposals from bioenergy small businesses to develop a community-scale preliminary design package of their products and/or processes and engage community stakeholders to assess desirability and feasibility of the small business' proposed design.

Bioenergy feedstock development and deployment can strengthen economic growth, national energy security, and environmental benefits through optimizing domestic biomass resources to produce biofuels, bioproducts, and biopower. Public perception and knowledge of bioenergy is highly variable [1], so despite the benefits, local communities may be unaware or uncertain about the available opportunities. Bioenergy small businesses are uniquely positioned to develop community-scale technologies and technological processes. Examples include small-scale solutions to recover nutrients and energy from waste, such as urban food waste; use of energy crops on marginal lands to manage fertilizer runoff; or use of algae to abate costs of wastewater treatment.

The preliminary design package should include identification and siting of appropriate feedstock(s), lab-scale testing of potential feedstock(s), relevant products (biofuel, bioproducts, and/or biopower), outreach to potential community stakeholder partner(s), and an education and outreach plan for the community, based on the bioenergy project.

Proposers are strongly encouraged to develop partnerships with local stakeholders in underserved communities such as those within Federally-designated Opportunity Zones [2]. Community stakeholders could include schools, hospitals, local restaurants and other businesses, non-profits, local government, or other local organizations. Applicants that propose partnerships with entities that operate at higher levels, like state or regional, should emphasize how their project will deliver measurable impact at the community level.

Appropriate projects could include, but are not limited to, a preliminary design package proposing:

- A conversion process treating local sources of biomass.
- Opportunities for use of the resulting product or products within the community.
- Cultivating energy crops to reduce fertilizer runoff to improve local water quality.
- Integration of the small business' technologies into complementary, existing local infrastructure.
- Small business' processes' ability to meet local regulatory needs (e.g., recycling rates or waste diversion goals).
- Replicability of the process in other communities.

Applications must:

- meaningfully include plans/methodology for local stakeholders' input in the development of their preliminary design package.
- include an education and outreach plan to demonstrate the planned benefits for the community.

Applications that propose the following will not be considered for award under this subtopic:

- Use versions of technologies that already exist at the community scale.

The main objective of a Phase I award is developing a preliminary design package of their technology, product, or process deployed at the community scale and derived from stakeholder input. In Phase I the majority of research emphasis is placed on evaluating and testing unknowns of integrating the technology at the community scale with their specific stakeholder group(s) rather than on developing a new technology. Some unknowns include technology performance parameters to better support the local economy and public acceptance of the technology.

Phase II of this topic involves deployment of the proposed technology into the community at a pilot scale.

Questions – Contact: Devinn Lambert, Devinn.Lambert@ee.doe.gov.

b. Cultivating a More Competitive Bioeconomy Through Strengthening Small Business Workforces

This subtopic solicits proposals that pilot a research-driven workforce development program or tool that can be widely applicable for the bioeconomy, establishing a partnership with business experts in bioenergy and/or inclusive workforce development.

Because biomass exists across geographically diverse regions (i.e., agricultural crops, forestry residues, Municipal Solid Waste, algae), people living in urban, suburban, and rural areas across the country could all benefit from careers and opportunities in the bioenergy industry. Increasing representation and inclusivity within the bioenergy industry will support a more competitive domestic science and engineering workforce to lead the way on innovation in the global economy [1].

The research project should investigate questions related to the representation and inclusivity within the business' workplace in relation to technical and operational challenges that could be inhibiting its commercial objectives in the bioeconomy. The overall outcome is to create a workforce development program or tool through this research that improves the commercialization potential of the business partner. Ideally outcomes of this R&D are scalable mechanisms, platforms, and technologies for increasing and improving diverse representation and equality within the bioeconomy's workforce. This could include, but is not limited to, demonstrated success in increasing recruitment of trained professionals with parallel skills from job sectors that have declined domestically, improving workplace retention from underrepresented backgrounds in Science, Technology, Engineering, and Math (STEM) and/or leadership positions; and correlating their project with these improvements.

Specific areas of interest under this subtopic include, but are not limited to:

- Development of software to foster experiential learning mediated by employer-educator partnerships that will ensure the alignment of bioenergy curriculum with workplace demands. This software or technology should address barriers associated with urban and rural areas as well as engaging people with underrepresented backgrounds within bioenergy R&D and deployment.
- Research to identify gaps in workforce development, recruitment, and retention within bioenergy fields of future workers/employees from underrepresented backgrounds and implementation of a multi-year data-driven program to address these gaps at the small business. The multi-year data-driven program will provide a roadmap for other small businesses.
- Development of artificial intelligence or other data-driven platforms that identify the impact of lacking or underdeveloped inclusive operational and/or commercial practices on workforce development that, if addressed, can improve business success and expansion.

Applications must include a robust evaluation plan to track and demonstrate the success of the workforce development program proposed.

Applications that propose the following will not be considered for award under this subtopic:

- Development of traditional curricula or courses on bioenergy topics.
- Conventional internship and training programs.

Phase I of this topic includes completion of research and beta-testing of the workforce development program or tool. Phase II includes the deployment of this technology at the bioeconomy business and scaling the tool to other businesses.

Questions – Contact: Devinn Lambert, Devinn.Lambert@ee.doe.gov.

References: Assistance with Teaming:

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

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

References: Subtopic a:

1. Radics, R., Dasmohapatra, S., and Kelley, S.S. "Systematic Review of Bioenergy Perception Studies." BioResource Vol. 10, Article 4, p. 8770-8794, https://bioresources.cnr.ncsu.edu/wp-content/uploads/2016/06/BioRes_10_4_8770_REVIEW_Radics_DK_Systematic_Review_Bioenergy_Perception_Studies_7627.pdf

2. U.S. Economic Development Administration. "Opportunity Zones." *US Department of Commerce*, 2020, https://www.eda.gov/opportunity-zones/

3. "Frequently Asked Questions | SBIR.Gov." Accessed December 4, 2020. https://www.sbir.gov/faqs/eligibility-requirements.

References: Subtopic b:

1. Harkavy, I., Cantor, N., and Burnett, M. "Realizing STEM Equity and Diversity through Higher Education-Community Engagement." White paper from NSF-funded grant, January, 2015, https://www.nettercenter.upenn.edu/sites/default/files/Realizing_STEM_Equity_Through_Higher_Education_Community_Engagement_Final_Report_2015.pdf

11. JOINT TOPIC: POLYMERS UPCYCLING AND RECYCLING

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

This topic supports the objectives of the Plastics Innovation Challenge to focus resources from across the DOE to create a comprehensive program to accelerate innovations that will dramatically reduce plastic waste in oceans and landfills and position the U.S as global leaders in advanced plastics recycling technologies and in the manufacture of new plastics that are recyclable by design.

Plastic production is energy intensive, and the bulk of this energy (and inherent value) is lost as post-use plastic is discarded. Plastics recycling is an extremely complicated challenge, in part due to the diversity of plastics that make up modern waste streams. As such, modern recycling technologies currently require plastics to be sorted into high purity, contaminant-free streams to create value in the recycling process.

This is a joint topic sponsored by the following EERE Technology Offices: Advanced Manufacturing and Bioenergy Technologies. The Vehicles Technology Office is also supporting a complementary subtopic supporting the objectives of the Polymers Upcycling and Recycling activity. Please see Subtopic c of Topic 17 for more information.

All applications to this topic must:

- Include projections for price and/or performance improvements that are tied to a baseline (i.e. internal baseline and/or published 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 only in the following subtopic:

a. Improving Plastics Compatibilization for More Efficient Recycling

This subtopic seeks proposals to develop new compatibilizers that may enable processing of plastic resins and the downstream recycling or upcycling of a mixed plastic stream. The scope of this work may span fundamental research investigating novel approaches to improve miscibility to applied approaches to characterize resins generated through processing with compatibilizers at scale.

Compatibilizers are materials or molecules that promote miscibility between disparate plastic resins, allowing for the direct recycling of mixed plastic. Traditionally, compatibilized post-consumer resins are most commonly downcycled for application as durable goods. The robust and scalable compatibilization of disparate plastic chemistries into a valuable same-cycled or even upcycled resin would dramatically improve the economics for materials recovery facilities (MRFs) and the deployment of recycling compatibilizers. In recent years, application of tailored copolymers has allowed for highly effectively compatibilization of disparate polymer chemistries to a resin of equal or improved properties [1, 2, 3]. Innovations targeting all moderate to high volume plastics will be considered for this topic, including polyamides, and copolymers such as Acrylonitrile Butadiene Styrene (ABS). However, preference will be given to applications that apply to plastics often prioritized by MRFs, specifically polyolefins, polyesters, and polystyrene, since broader collection infrastructure is most advanced for these materials. The resulting mixed resins must possess mechanical and optical properties that allow for same cycling or displacement of virgin material.

Areas of interest include, but are not limited to:

- Demonstration of a compatibilizing technology that can be applied to two or more commonly discarded plastics into a product of performance commensurate with virgin feedstock.
- Application of a novel compatibilizer material, including but not limited to tailored copolymers, bio-based feedstocks, or inorganics.
- Application of a novel compatibilization process.
- An improvement in the energy efficiency of the recycling process.
- Development of a mixed polymer resin that is capable of substituting virgin polymer in any moderate or high-volume application.

Questions – Contact: Melissa Klembara, Melissa.Klembara@ee.doe.gov or Gayle Bentley, Gayle.Bentley@ee.doe.gov

References: Subtopic a:

1. SPI: The Plastics Industry Trade Association. “Compatibilizers: Creating New Opportunity for Mixed Plastics.” May, 2015, https://www.plasticsindustry.org/sites/default/files/Compatibilizers%20Whitepaper%20%28Version%201.0%29_0.pdf

2. Eagan, James M., Jun Xu, Rocco Di Girolamo, Christopher M. Thurber, Christopher W. Macosko, Anne M. LaPointe, Frank S. Bates, and Geoffrey W. Coates. “Combining Polyethylene and Polypropylene: Enhanced Performance with PE/ i PP Multiblock Polymers.” Science 2018 355 (6327), 814–816. https://doi.org/10.1126/science.aah5744.

3. Li, Huanmin, Xianwei Sui, and Xu-Ming Xie. “High-Strength and Super-Tough PA6/PS/PP/SEBS Quaternary Blends Compatibilized by Using a Highly Effective Multi-Phase Compatibilizer: Toward Efficient Recycling of Waste Plastics.” Polymer 123 (August 2017): 240–46. https://doi.org/10.1016/j.polymer.2017.07.024.

4. Jun Xu, James M. Eagan, Sung-Soo Kim, Sanshui Pan, Bongjoon Lee, Kristine Klimovica, Kailong Jin, Ting-Wei Lin, Micah J. Howard, Christopher J. Ellison, Anne M. LaPointe, Geoffrey W. Coates, and Frank S. Bates, "Compatibilization of Isotactic Polypropylene (iPP) and High-Density Polyethylene (HDPE) with iPP–PE Multiblock Copolymers." Macromolecules 2018 51 (21), 8585-8596, https://pubs.acs.org/doi/10.1021/acs.macromol.8b01907

12. 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

DOE'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 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.

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.

NOTE: In addition to the subtopics below, BTO is considering proposals in response to Topic 13 – Joint Topic: Advanced Building Construction Technologies. BTO is also considering proposals in response to Topic 20 – Joint Topic: CABLE Materials and Applications through subtopics (c) Non-metallic Heat Exchangers, (d) Ice-storage and other thermal storage-related systems, and (e) Electric Systems – Generators and Motors.

BTO seeks grant applications in the following subtopics:

a. Remote Building Data Collection Technologies for Virtual Audits and Inspections

This subtopic solicits innovative approaches for leveraging remote sensing data collection and curation techniques to automate the importing of building characteristic data into existing virtual audit and inspection platforms.

Current conditions make boots-on-the-ground audits difficult to execute, limiting the ability to identify energy efficiency opportunities safely and cost-effectively through audits and inspections. Recent advances in remote data collection make it possible to evaluate building energy dynamics and opportunities for upgrades using visual and thermal imagery. Remote sensing data, including visual imagery and other sensor data types (such as infrared or other spectrums) can be processed and leveraged for the pre-population of building characteristics for use in existing building evaluation platforms. For more information on this topic, applicants should refer to BTO's building data science research, resources, and tools website [1].

Approaches should leverage standardized data systems, such as Audit Template, BuildingSync, HPXML, ASHRAE 223P, and other relevant management tools to synthesize and aggregate remote sensing data for automated import into building energy evaluation tools. Proposals should build upon existing tools to meet the requirements for a remote audit or virtual building inspection and support further identification of energy efficiency measure opportunities on a site by site basis with similar results to traditional auditing techniques. BTO encourages applicants to include identified sites in their proposals where the proposed outcome can be tested and demonstrated in the field.

Questions – Contact: Harry Bergmann, harry.bergmann@ee.doe.gov

b. Building Energy Modeling

This subtopic solicits R&D proposals for new methods, tools, applications for whole building energy modeling (BEM) and closely related areas. BTO's goal is to expand the effective use of BEM in all use cases, supporting energy efficiency, demand flexibility, or both.

Whole building energy modeling (BEM) is a multi-purpose tool for building energy efficiency. At the individual building project level, it supports optimized design of new and retrofitted buildings and districts, HVAC equipment selection, sizing, and control design, code-compliance, ratings and certificates, and incentives. BEM on prototypical model supports the development of energy-efficiency codes, design guides, incentive programs, and products. BEM also has some applications in building operations. Although BEM typically implies physics-based modeling, reduced-order, data-driven, and hybrid models have been demonstrated to be sufficient for some applications and have both model development and execution time advantages over physics-based models.

Proposals may target any BEM use case (e.g., design, code-compliance, portfolio analysis), any sub-task associated with one or more BEM use-cases (e.g., Building Information Model-to-BEM, model input calibration, quality assurance), any building or project type (e.g., new or existing, commercial or residential, individual building or campus), and any approach (e.g., physics-based, data-driven, hybrid). Although DOE funds the development of a number open-source physics-based BEM tools and packages, use of DOE-funded BEM tools is not required. Applicants should explicitly state which existing tools (in whole or in part) they will be using and which (if any) they plan to develop as part of the proposed work.

Interested applicants may refer to BTO's draft research & development opportunities document for more information about specific barriers to the effective adoption of BEM and possible initiatives to address them [1].

Questions – Contact: Amir Roth, Amir.Roth@ee.doe.gov

Return to Table of Contents

c. Solid-State Lighting Technologies

This subtopic solicits R&D proposals for innovative solutions in advanced solid-state lighting technologies (SSL). There are three subtopic areas of interest for Lighting R&D. Please note that awards may not be made in all areas, and the distribution will depend on the number and quality of proposals received. In all cases, project benefits should be demonstrated and validated as part of the proposed project structure, and clear demonstration of product or technology capabilities is required for consideration for advancement to Phase II funding. For more information on these topics, applicants should refer to the Lighting Research and Development Opportunities document [1].

1. SSL Technology development – DOE seeks product- and market-facing technology development that achieves energy savings in addition to the 2019 baseline or advanced functionality based on the features of SSL technology. Gains in energy savings and new functionality can be achieved through optical delivery, intensity controls, source and fixture efficiency, and spectral optimization. Examples of product or technology advancement include energy savings in SSL applications include, but are not limited to, general illumination, increased productivity, enhanced well-being, safety improvements, and reduced environmental impacts.
2. Manufacturing Technologies and Materials for SSL –DOE seeks additive and sustainable manufacturing techniques and materials for SSL for all portions of the value chain. These techniques should enable manufacturing at scale for a wide variety of product configurations with reduced component count, inventory, and production time with potential for reduced cost. Also relevant are advancements in product designs and materials that advance the capabilities of additive and/or sustainable manufacturing without degrading performance or lifetime of luminaries. Materials should reduce the embodied energy of the luminaire and should be readily recycled, reused, or repurposed. This subtopic supports DOE's crosscutting emphasis to enable advancements in Advanced Manufacturing as part of the Administration's emphasis strengthening U.S. leadership in the Industries of the Future; however, SBIR applicants for lighting-specific manufacturing should apply to this topic.
3. SSL Material Science – DOE seeks research to advance understanding of SSL degradation mechanisms, carrier dynamics, performance under different operating regimes, photon generation and control, and downconverter properties. Research should advance the understanding of material-performance relationships for SSL technologies to enable energy saving and performance enhancement, in a way that improves the technology's commercial applications. Application of findings to novel device materials, SSL device architectures (including but not limited to general illumination), or modeling software should be part of the proposed project structure.

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

d. Advanced Building Control Systems for Controlled Environment Agriculture (CEA)

This subtopic solicits proposals investigating innovative solutions for the refinement, integration, and expansion of existing building management systems and tools for CEA applications. Advanced building control systems for CEA, can be considered analogous to building management systems, but customized for integration into the unique processes and requirements of indoor farms. Current CEA control systems may include some level of connectivity between equipment of moderate efficiency and are intended to optimize the internal conditions for maximum plant quality and growth. This limited amount of integration/connectivity with other building management systems does not allow for smart decisions to be made regarding how and when equipment should operate to optimize energy and water costs, provide grid benefits while still maximizing plant quality and growth. CEA is a rapidly expanding market and currently DOE estimates that these technologies, when paired with high-efficiency integrated equipment,

Return to Table of Contents

have the potential to save 50-100 TBTu/yr in the U.S. For more information, applicants should refer to the listed building automation system project pages [1, 2, 3].

Specifically, DOE is interested in proposals in the following research areas:

- Development of Grid-Interactive Integrated Controls that provide capability for the implementation of demand management strategies.
- Refinement or expansion of existing open-source building management systems for use in indoor agriculture. DOE has funded research on open-source building management-related systems such as BEMOSS™ and VOLTTRON™. These systems have focused solely on commercial and residential applications and would need further refinement to adapt to the needs of CEA facilities.

Preference will be given to those applications that address multiple building end use systems including lighting, ventilation, heating, air conditioning, humidity, and water, and plug and process loads.

Questions – Contact: Cedar Blazek, cedar.blazek@ee.doe.gov

e. Healthy Efficient Buildings

This subtopic solicits proposals for advanced technologies to enable healthy and efficient residential and commercial buildings. There are two subtopic areas of interest for Healthy Efficient Buildings. Note that awards may not be made in all areas, and the distribution will depend on the number and quality of proposals received. In all cases, project benefits should be demonstrated and validated as part of the proposed project structure, and clear demonstration of product or technology capabilities is required for consideration for advancement to Phase II funding. For more information, applicants should refer to BTO's Building America Program Research-to-Market Plan [1].

1. Low-cost, Smart Ventilation Systems and Components for Healthy, Efficient Residential Buildings- DOE seeks to identify and encourage development of innovative ventilation system and/or component technologies with the potential to improve IAQ and comfort in new and existing homes, with little or no energy penalty and very low incremental cost to builders and contractors.

   Recent research and field-testing by BTO and others have identified ventilation system technologies needed to help the industry reliably achieve optimal indoor air quality (IAQ), comfort, and energy efficiency in modern, "high performance" residential buildings. Ventilation system performance, reliability, and cost continue to be barriers to healthy, high performance homes, for both new construction and energy retrofits. Furthermore, ventilation is recommended by ASHRAE as the first building-related risk mitigation strategy for COVID-19.

   Preference will be given to technology solutions that are applicable to both new construction and the existing building stock. While modest feasibility studies are appropriate for Phase I funding, applications for these subtopics should be transitioning to manufacturing by Phase II to be considered for further funding. BTO strongly encourages applicants to include a strategy for obtaining manufacturing partners by the end of Phase 1 as a part of their commercialization plan.

   Specifically, DOE is interested in the following IAQ and comfort control technology applications:

   - Low-cost, reliable add-on sensors (e.g., flow sensors) and controls for improved commissioning, operation, and maintenance of ventilation systems.
   - Smart ventilation/IAQ tools (sensors, controls, hardware, software) that integrate with systems and components to optimize IAQ and minimize energy penalties, based on indoor conditions (i.e.,

temperature, RH, pollutant levels), outdoor conditions (i.e., temperature, RH, and/or pollutant levels, including smoke), occupancy, and other variables such as weather forecast data.

Questions – Contact: Eric Werling, eric.werling@ee.doe.gov

2. Health-Energy Nexus in Commercial Buildings- DOE seeks innovative research, analysis, and development of building technologies and solutions that improve building energy performance and maintain comfortable, healthy, productive indoor environments despite disruptive events such as natural disasters, the spread of infectious disease, and grid interruptions.

   With disruptive events such as COVID-19, [2, 3] there is a need for research, analysis and the development of resource efficient, resilient technologies and strategies to support the U.S. building stock in managing healthy, efficient, and resilient buildings.

   Specifically, DOE is interested in the following:
   - Measuring, sensing, and evaluating the trade-offs associated with indoor air quality, occupant comfort, health, and energy use in commercial buildings.
   - Research to better understand air transport in commercial buildings, segmented by system type and/or sector under various conditions of re-occupancy and ongoing operation as related to specified resilient scenarios.
   - Development of novel efficient air-cleaning systems, advanced filtration systems, and/or surface treatments.

Questions – Contact: Cedar Blazek, cedar.blazek@ee.doe.gov

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

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Renewable Energy, April, 2019, https://www.energy.gov/sites/prod/files/2019/04/f61/bto-bem-rdo-041719.pdf

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3. U.S. Department of Energy. "Turn Key: Open Source Software Solutions for Energy Management of Small to Medium Sized Buildings (DE-FOA-0000822)." U.S. DOE, Office of Energy Efficiency and Renewable Energy, March 28, 2013, https://www.energy.gov/eere/buildings/articles/turn-key-open-source-software-solutions-energy-management-small-medium-sized

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1. U.S. Department of Energy. "Building America Research to Market Plan." U.S. DOE, Office of Energy Efficiency and Renewable Energy, 2020, https://www.energy.gov/eere/buildings/downloads/building-america-program-research-market-plan

2. Whiting, K. "Coronavirus isn't an outlier, it's part of our interconnected viral age." *World Economic Forum*, March 4, 2020, https://www.weforum.org/agenda/2020/03/coronavirus-global-epidemics-health-pandemic-covid-19/

13. JOINT TOPIC: ADVANCED BUILDING CONSTRUCTION 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

The Advanced Building Construction Technologies topic seeks proposals that integrate energy-efficiency solutions into highly productive U.S. construction practices for new buildings and retrofits. This is a joint topic sponsored by the EERE Building Technologies Office (BTO) and the Advanced Manufacturing Office (AMO), bringing together BTO's focus on buildings technologies with AMO's manufacturing materials, processes, and product focus.

This topic supports DOE's Advanced Building Construction (ABC) initiative, the objective of which is to help realize the vision of a modernized U.S. construction industry that delivers high-performance, low-carbon new buildings and retrofits at scale. ABC approaches are intended to result in residential and commercial buildings that have ultra-efficient energy performance, fast on-site construction, and renovation timelines, and are affordable and provide additional value to owners and tenants through improved aesthetics, comfort, resilience, and occupant health.

ABC technologies and practices focus on a variety of innovations intended to improve the energy efficiency of buildings and the productivity of building construction processes, including: new building materials, 3D printing and other new fabrication methods, offsite manufacturing of building components, robotics applications for construction, next-generation building envelope, HVAC and water heating, and digitization.

There are four sub-topics for the Advanced Building Construction (ABC) R&D topic. Please note that awards may not be made in all subtopics, and the distribution of awards in this topic will depend on the quality of proposals received. In all cases, project benefits should be demonstrated and validated as part of the proposed project structure, and clear demonstration of product or technology capabilities is required for consideration for advancement to Phase II funding.

In addition, all proposals to this topic must:

- Propose a tightly structured program which includes advanced building construction-relevant technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative.
- Provide evidence that the proposer has relevant advanced building construction 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.
- Include an energy savings impact as well as a preliminary cost analysis.
- Report all relevant performance metrics.
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Applications must be responsive to the following subtopics. Applications outside of these subtopic areas will not be considered.

a. Diagnostic Technologies and Tools

This subtopic solicits proposals for innovative technologies and tools critical for design and manufacturing of retrofit solutions for buildings.

Technologies that can characterize the key energy and moisture performance-related properties of existing opaque envelopes could facilitate retrofit adoption and aid offsite manufacturing by quantifying the benefit of retrofits, pinpointing specific areas to retrofit, determining if an envelope retrofit can be safely conducted, and verifying post-retrofit performance.

Novel nondestructive testing and sensing technologies; simplified, lower-cost physical testing platforms; and novel, low-computational expense data acquisition and synthesis software have the potential to significantly expand the impact and reach of envelope diagnostic technologies. For more information, applicants should review BTO's DRAFT Research and Development Opportunities Report for Opaque Building Envelopes [1] and ASHRAE's Review of Non-Destructive Techniques for Building Diagnostic Inspections [2]. Proposals must include supporting data acquisition and processing software that delivers actionable insights to testing personnel. All solutions should minimize setup and teardown effort and time, as well as avoid disruption to building operations or occupants during testing.

Specifically, DOE seeks proposals in areas that include, but are not limited to:

- Development of novel air leakage diagnostic metrology that delivers accurate and fast results regardless of outdoor weather conditions and provides location and quantified extent of infiltration/exfiltration. Technologies that reduce the complexity and effort required to test medium and large commercial buildings are also of interest.
- Development of novel diagnostic metrology for envelope moisture performance without needing to remove exterior cladding. Detection of pre-existing moisture and water intrusion issues within envelopes (e.g., exterior wall assemblies) is an important step when considering envelope retrofits, such as those envisioned by BTO's ABC Initiative.

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

b. Low-cost, High-R Insulation

This subtopic solicits proposals for development of low-cost, high-R factor insulation (targeting under $0.05/inch*R and no greater than $1/square foot per inch) using readily available and scalable manufacturing processes.

Proposed solutions should be compatible with existing tooling at the construction site or incorporate a substantial change in installation method that yields lower overall cost, labor effort, and installation time. High R-value per inch insulation materials that could reduce the cost and complexity of envelope retrofits could make façade retrofits of existing buildings much more feasible and accessible. For more information, applicants should read BTO's DRAFT: Research and Development Opportunities Report for Opaque Building Envelopes report [1].

Proposals for sustainable insulation material innovations must meet the cost target and have an R-value/inch of 8 or greater are of interest. Potential areas of for research and development include, but are not limited to, the following:

- Development of durable aerogel insulation using continuous, high-throughput production methods (e.g., in bead form, 3D printing, etc.) at atmospheric processing conditions and in practical building insulation form factors. Aerogels often are very brittle, use very expensive material feedstocks, and utilize complex and expensive manufacturing processes. DOE seeks innovations that result in significant cost reductions of 3-5 times compared to current aerogel costs.
- Development of durable, ultralow-cost vacuum insulation panels (VIPs) using high-throughput production methods. VIPs are often regarded as one of the most promising state-of-the-art building insulation solutions given their potential to achieve ultra-low thermal conductivities. While commercially available, VIPs are very expensive, relegating them to niche applications. To make VIPs truly affordable for the building sector, costs need to be cut by a factor of >3-5 times current VIP cost. Dialing back the thermal performance (e.g., to whole panel thermal resistance of R10-15/inch), for instance, could offer extra degrees of freedom on the material, barrier film, vacuum creation, and processing side to enable new cost curves and deliver truly low-cost VIPs.
- Development of novel form insulation (spray foam and rigid foam board) that offer improved insulation values at comparable costs.

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

c. Advanced Building Equipment Technologies

This subtopic seeks proposals for the design of new energy efficient advanced building equipment technologies.

The ABC Initiative focuses on several key areas for building equipment technologies. HVAC and water heating technologies influence the design of new buildings and retrofit opportunities, and by taking these technologies into consideration will allow DOE to expand the ABC R&D portfolio beyond existing state-of-the art integrated heat pump (IHP) solutions. DOE is particularly interested in proposals that leverage previous building equipment R&D to make solutions that are relevant to ABC. For example, IHP technology and multi-functional space-conditioning unit with water heating function can facilitate whole-building, deep energy retrofits in the residential sector by integrating the solution into the building itself, like variable refrigerant flow systems. These technologies lead to significant energy savings (greater than 50%) by recovering condensing waste heat in the cooling season and providing dedicated or desuperheating heat pump water heating. This type of heat exchanger utilizes the high temperature of the superheated refrigerant gas to heat water. For more information, applicants should read BTO's Energy Savings Potential and RD&D Opportunities for Non-Vapor-Compression HVAC Technologies report [1].

This subtopic seeks proposals in the following specific areas:

- Energy and work recovery technologies that significantly advance the state-of-the-art for HVAC and water heating equipment. DOE is particularly interested in technologies that do not rely on passive and expensive materials but could use active (non-vapor compression) technology to transfer waste heat for preheating use. Applicants must demonstrate how the technologies could be incorporated into equipment design.
- New approaches, technologies, and concepts that address air and water distribution systems with improved energy efficiency and occupant comfort.

Given the wide range of ABC building equipment technologies suitable for this subtopic, specific cost targets are not defined in the subtopic; however, applications must outline expected costs of the proposed design, providing analysis to support claims made. Applicants should also consider system approaches at the whole building level.

Applications must demonstrate greater than or equal to 30 percent energy efficiency as compared to state-of-the-art or Energy Star equipment, little to no increase in physical size, or little to no increase in difficulty to clean to maintain as-new performance as compared to state-of-the-art or Energy Star equipment, as well as a payback period less than or equal to 5 years.

Examples of product or technology advancement include energy savings in HVAC and water applications, including but not limited to general discrete HVAC and water heating equipment, increased productivity, enhanced comfort, and reduced environmental impacts.

Questions – Contact: Fredericka Brown, Fredericka.brown@ee.doe.gov

d. Advanced Building Construction Digitization Solutions

This subtopic solicits proposals that identify and encourage development of innovative information technology solutions that support the objectives of the ABC Initiative and construction digitization, including but not limited to, the application of artificial intelligence and machine learning.

According to a 2017 report by McKinsey Global Institute (MGI), the construction industry and its associated manufacturing sector sorely underinvest in the technology and digital tools that would enable significant productivity gains [1]. MGI analysis suggests that lower digitization in the construction industry has contributed to productivity decline, which leads to cost/price escalation, which in turn is a well-documented deterrent to energy efficiency measure adoption. BTO believes that increased digitization and improved construction productivity will lower barriers to energy efficiency and building performance improvements, increase building affordability, and improve building reliability.

Complex software and faster computing power, combined with artificial intelligence and machine learning, allow for the rapid intake and processing of information. For energy-efficient construction, machines can intake visual images, energy analysis and modeling, and other inputs to directly translate data into the fabrication of building components including walls, roofs, or interior design features. This process, also known colloquially as "art-to-part," can help bridge the gap between a traditional building and a high-performance building with smarter, energy-efficient components.

Research areas being considered under this topic include but are not limited to "Building Information Modeling (BIM) to fabrication" applications, construction process digitization for process improvement (4D/5D CAD applications), automated QA/QC applications, and automated Building Commissioning solutions.

Preference will be given to technology solutions that are applicable to both new and existing buildings. While modest feasibility studies are appropriate for Phase I funding, applications for this subtopic should be transitioning to manufacturing by Phase II to be considered for further funding.

Questions – Contact: Eric Werling, eric.werling@ee.doe.gov

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1. U.S. Department of Energy. "Advanced Building Construction Initiative." U.S. DOE, Office of Energy Efficiency and Renewable Energy, 2020, https://www.energy.gov/eere/buildings/advanced-building-construction-initiative

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

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

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

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Return to Table of Contents

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2. Goncalves, M., Simoes, N., et al. “A review of the challenges posed using vacuum panels in external insulation finishing systems.” Applied Energy, Vol. 257, 3.5. Economic viability (Page 9), January, 2020, https://www.sciencedirect.com/science/article/pii/S0306261919317155

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1. McKinsey Global Institute. “Reinventing Construction: A Route to Higher Productivity.” Executive Summary, February 2017, https://www.mckinsey.com/~/media/McKinsey/Industries/Capital%20Projects%20and%20Infrastructure/Our%20Insights/Reinventing%20construction%20through%20a%20productivity%20revolution/MGI-Reinventing-Construction-Executive-summary.pdf

14. GEOTHERMAL 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

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].

For FY 2021, GTO’s SBIR focus is on R&D related to naturally occurring tracers to characterize geothermal reservoirs. Naturally occurring tracers can include critical materials, minerals, isotopes, etc. that are found in geothermal fluids as they exist in the reservoir. Analysis and modeling of such naturally occurring tracers can be used to better characterize key reservoir parameters leading to improved understanding and performance of geothermal reservoirs, further expanding the usage and utility of geothermal energy. Because improving the understanding of critical materials and other natural tracers within geothermal reservoirs will inform future critical material recovery efforts associated with geothermal systems, this technology area also supports the Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals, Call to Action 4: Improve Understanding of Domestic Critical Mineral Resources [3].

A Phase I application should focus on proof of concept, bench scale testing, and/or preliminary model design that are scalable to subsequent Phase II development. Applications must be responsive to the subtopic below. Any application outside of this area 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;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Note: In addition to the subtopic below, GTO is considering proposals in response to Topic 20 - Joint Topic: CABLE Materials and Applications through subtopic g: “Geothermal: Direct Use and Electricity Generation Applications.”

Grant applications are sought in the following subtopic:

a. Usage of Critical Materials, Minerals, Isotopes, and other Naturally Occurring Tracers to Characterize Geothermal Reservoirs

In this subtopic, GTO solicits innovative research and development projects to better characterize geothermal reservoirs by utilizing naturally occurring tracers such as critical materials (lithium, cobalt, etc.), minerals, isotopes, or other components of complex geothermal fluids such as silica or salts.

Optimization of heat exchange performance in geothermal reservoirs is critical; fractures are the conduits for heat transfer and therefore the distribution, length, aperture, connectivity, flowing pressure, thermal conductivity of fractures impact fluid residence time, fracture connectivity, and reservoir volume, all of which control the performance and sustainability of a geothermal reservoir.

Applications may include, but are not limited to the following:

- utilizing fluid-rock interactions of naturally occurring tracers to characterize the fundamental characteristics of the geothermal reservoir;
- chemical and thermodynamic interactions between critical materials/minerals and other components of complex geothermal fluids (e.g. silica, salts, etc.);
- obtaining an understanding on the specific source of the critical material(s)/isotopes within the geothermal reservoir; and/or
- chemical effects of geothermal brines reinjected into the reservoir.

Innovation into extraction technologies for critical materials from geothermal brines or other fluids will be deemed non-responsive and not receive external merit review.

Return to Table of Contents

In Phase I, applicants should focus on proof-of-concept towards a preliminary geologic model with updates on reservoir parameters including findings from the project. In Phase II, applicants should propose technical metrics regarding improvements to understanding of reservoir parameters, plant efficiency, and costs/revenue that can be benchmarked to existing technologies.

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

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1. U.S. Department of Energy. "Geothermal Technologies Office." U.S. DOE, Office of Energy Efficiency and Renewable Energy, https://energy.gov/eere/geothermal

2. U.S. Department of Energy. "GeoVision." Geothermal Technologies Office, U.S. Department of Energy, https://www.energy.gov/eere/geothermal/geovision

3. U.S. Department of Commerce. "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals." U.S. Department of Commerce, https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf

15. HYDROGEN AND FUEL CELL 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

The Hydrogen and Fuel Cell Technologies Office (HFTO) (https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office) is part of DOE's comprehensive energy portfolio to enable energy security, resiliency, economic value, and environmental benefits for the nation. The mission of HFTO is to conduct research, development and innovation to enable the adoption of hydrogen and fuel cell technologies across multiple applications and sectors at scale. To achieve this goal, HFTO invests in 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.

Hydrogen fuel can be produced from diverse domestic resources, such as natural gas, coal, and biomass, as well as from renewables using methods such as direct or indirect water splitting. Hydrogen fuel cells are an attractive technology to power zero-emissions medium- and heavy-duty vehicles, such as trucks and buses, as well as marine, rail, mining, and aviation applications. They offer several advantages over incumbent technologies: higher efficiency, reduced emissions, higher torque, and no noise pollution. Additionally, they offer fast fueling and adequate fuel storage for applications demanding longer range.

The HFTO program funds research and development to address key technical challenges for both fuel cells and hydrogen fuels (production, delivery, and storage) with medium- and heavy-duty vehicle applications as an emerging area of focus.

Applications submitted to any of these subtopics must:

- Propose a tightly structured program including 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 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.

Applications are sought only in the following subtopics:

a. Novel PEM Fuel Cell Membrane Electrode Assemblies for High Efficiency and Durability in Heavy Duty Applications

This subtopic solicits proposals for novel and innovative concepts that advance the development and integration of electrocatalysts, membranes, ionomers, and/or gas diffusion layers for use in heavy-duty direct hydrogen polymer electrolyte membrane (PEM) fuel cells, with a focus on high durability and high fuel efficiency.

Medium- and heavy-duty PEM fuel cell electric vehicles operating on hydrogen offer several advantages over incumbent technologies, including higher efficiency, reduced emissions, higher torque, and no noise pollution. Medium- and heavy-duty truck applications require a lifetime of up to one million miles, and therefore require fuel cells with innovative membrane, catalyst, and electrode structures with enhanced durability. Significantly longer vehicle lifetimes and range requirements also mean that hydrogen fuel costs comprise a greater proportion of vehicle lifecycle cost. As such, increased fuel cell efficiency is a key parameter for economic viability.

The heart of the PEM fuel cell is the membrane electrode assembly (MEA). MEAs rely on expensive Platinum Group Metals (PGM) as catalysts within the electrodes. A critical path to reducing fuel cell cost, in support of DOE's Critical Minerals Initiative, is to reduce the amount of PGMs used in fuel cells, while maintaining fuel cell durability and efficiency. For state-of-the-art MEAs, durability and power output decreases with lower PGM loading. This makes it difficult to meet 2030 DOE target of 25,000 hours durability for medium- and heavy-duty transportation applications while simultaneously meeting targets for system cost ($80/kW) and efficiency (68% peak) [1]. In the most demanding applications, the conditions include operation in the presence of fuel and air impurities, starting and stopping, freezing and thawing, and humidity and load cycling that result in mechanical and chemical stresses on fuel cell materials, components, and interfaces.

To expedite heavy-duty fuel cell competitiveness, the DOE launched the Million Mile Fuel Cell Truck consortium (M2FCT), which includes national labs in partnership with universities and industry to accelerate R&D that would enable meeting a fuel cell durability of a million miles. M2FCT is a large-scale, comprehensive effort to enable widespread commercialization of fuel cells for heavy duty applications. The M2FCT cross-disciplinary fuel cell R&D Consortium is focused on achieving aggressive targets for fuel cell MEAs that meet efficiency, durability, and cost [2].

Designs for fuel cell MEAs submitted in response to this subtopic should demonstrate significant progress toward meeting the M2FCT 2025 MEA target of 2.5 kW/gPGM power output (1.07 A/cm2 current density at 0.7 V, <0.3 mg/cm2 PGM loading) after running a heavy-duty accelerated stress test equivalent to 25,000 hours.1

In addition, applications must include the following:

[1] Target is for MEA-level performance with total PGM loading constrained to 0.3 mg/cm^2. Performance is measured after a heavy duty accelerated stress test equivalent to 25,000 hours. MEA test conditions: 88°C, 2.5 atm, SR: 1.5 cathode/2 anode, 40% relative humidity, integral cell conditions.

- Details of any novel low-PGM cathode oxygen reduction catalyst synthesis, novel membrane synthesis, improved gas diffusion and ionomer materials, and electrode layer design and integration;
- Details of how the approach improves durability and efficiency of low-cost fuel cells under realistic conditions; and
- Details of how the approach decreases degradation in new and state-of-the-art material sets.

Phase I proposals should provide substantial evidence that the proposed MEA design and materials represent a significant improvement in efficiency and/or durability over state-of-the-art PEMFC MEAs that are used in current fuel cell vehicle applications. Applicants should collaborate with M2FCT where possible, including testing and utilizing appropriate accelerated stress tests (ASTs).

Questions – Contact: Donna Ho, Donna.Ho@ee.doe.gov

b. Innovative Approaches to Minimize Boil-off Losses from Liquid Hydrogen Storage Systems

This subtopic solicits proposals for novel concepts, ranging from component level to system scale, that substantially mitigate, recapture, or beneficially use boil-off from either bulk stationary storage of liquid hydrogen, transfers of liquid hydrogen, or liquid hydrogen storage systems onboard transportation vessels, such that boil off is less than 0.1%. Examples include but are not limited to development of novel materials and components that manage heat transfer from liquid equipment, concepts to capture and recover boil-off vapor, and innovative integration of station components (e.g., cryo-pumps and liquid dewars).

Hydrogen is transported and stored in liquid form in applications where demand is significant and stable, but where overall regional hydrogen demand is not large enough to warrant the use of pipelines. Sectors that use liquid hydrogen include space applications, industrial facilities (e.g. metal processing plants), and fueling stations for hydrogen vehicles and material handling equipment. Given the exceptionally low boiling point of liquid hydrogen (20 K), boil-off losses throughout the delivery pathway, which includes trucking, offloading to a facility, storage and use of the liquid hydrogen at the facility, can be a substantial cost contributor. Mitigation of these boil-off losses will become increasingly important as newer applications for liquid hydrogen emerge, e.g. in heavy-duty transportation, marine vessels, and rail vessels where hydrogen may be stored onboard in liquid form. These applications will require a wide range of onboard liquid hydrogen storage capacities, from around 60 kg for long-haul Class 8 trucks, to thousands of kgs for larger marine vessels. Boil-off losses in these use cases are intimately tied to dormancy and duty cycles and could be just as significant as those present in refueling stations. Strategies to eliminate the boil-off of fuels in general have been explored in many other industries to date, including the aerospace and liquefied natural gas (LNG) sectors. Approaches that have been studied include innovative methods of insulation, mixing of layers within liquid dewars to prevent stratification, use of cryo-coolers, recovery of boil-off to power ancillary equipment, and sophisticated cryo-pump designs. Many of these approaches are capital-intensive, which prohibits their widespread use and would hinder any ability to achieve HFTO's hydrogen cost targets.

Phase I of the effort is expected to involve an in-depth analysis that includes a preliminary design of the selected component(s) or strategy, as well as specific research, development, and (if reasonable within the Phase I budget) proof-of-concept testing of any new components or processes to show that they have the potential to be incorporated into a liquid hydrogen storage system. Phase II should focus on prototype development and testing at a scale relevant to demonstrate the viability of the concept for the specific application or use case being targeted. Identification of commercialization strategies and a market analysis should also be included. Identification of potential commercialization partners, with indication of commitment, would greatly strengthen Phase II proposals.

Questions – Contact: Zeric Hulvey, Zeric.Hulvey@ee.doe.gov

c. In-line Filter for Particulate Matter at Heavy-Duty Hydrogen Fueling Stations

This subtopic seeks concepts that can remove particulate contaminants from hydrogen fuel at fueling stations for medium- and heavy-duty vehicles.

Hydrogen fueling stations for fuel cell vehicles conventionally use filters to prevent particulate matter from contaminating the vehicle [1]. Limits for particulate matter in hydrogen fuel for vehicles have been established by the Society of Automotive Engineers (SAE) J2719 and the International Organization for Standardization (ISO) 14687 standards.[2] Per SAE J2719, particulate matter must be limited to 1 mg/kg H2, and 99% of particulates larger than 5 micrometers should be removed before reaching a vehicle.[3] Filters that meet SAE J2719 requirements are available for light duty vehicle fueling stations, where the peak flow rate is less than 2 kg/min. However, filters that can support the need to fill at the higher flow rates (60 kg or more in approximately 6-10 minutes), needed for fueling medium- (MD) and heavy-duty (HD) vehicles, are not commercially available.

Proposed filter concepts must be capable of continuous operation at -40°C and pressures of 700-1,000 bar. The unit design should account for any occurring pressure drop due to the filtration. The unit developed must be capable of installation within a hydrogen dispenser, and potentially, at multiple points in the fueling system (e.g. between compressor stages) to mitigate the consequences of failure. The unit must be capable of an average flow rate of approximately 10 kg H2/min [4].

Phase I proposals should include concept development and feasibility evaluation of filter materials and design for key metrics, including durability under 1,000 bar pressure and -40°C temperature, and ability to meet SAE J2719 particulate requirements. Further, the resistance across the filter should not generate sufficient pressure drop to impact the desired flow rate and dispensing pressures.

Phase II proposals will involve incorporation of the filter design into a device that should additionally be easily field replaceable, and validation of the device. Phase II proposals must identify service life and provide criteria for filter replacement. Concepts proposed should target a capital cost of $500 or less.

Questions – Contact: Neha Rustagi, Neha.Rustagi@ee.doe.gov

d. Efficient Chillers for Hydrogen Pre-cooling at Heavy-Duty Hydrogen Fueling Stations

This subtopic solicits proposals for R&D of novel concepts that will allow for maximum hydrogen refueling of medium- and heavy-duty (MD/HD) vehicles compared with traditional fuel routes.

Interest in the use of fuel cells onboard MD/HD vehicles is growing rapidly, due to their potential to enable high-power operation, long range, and zero emissions. Deployment of MD/HD fuel cell vehicles will require the development of novel hydrogen fueling technologies that can enable fills that are over five times faster than those of light-duty hydrogen fueling stations. While a fueling protocol for MD/HD fuel cell vehicles has not yet been established, the DOE's target for hydrogen fueling of 700 bar onboard storage tanks include a fill rate of 10 kg/min with a hydrogen gas temperature of -40 °C [1]. Hydrogen chillers that can achieve -40 °C fills are commercially available, but do not meet the flow rate and cooling capacity requirements of MD/HD vehicles. Cooling capacities of up to 100 kW will be necessary to facilitate 10 kg/min refueling at -40 °C.2

Proposed concepts must adhere to the flow rate and temperature standards of 10 kg/min (maximum) and -33 °C at the point of dispensing within 30 seconds; however, viable alternatives to temperature standards will be considered. Proposed concepts can range in scope from component to system level. Examples include, but are not limited to, chillers that enable on-demand supply of cold hydrogen, short-term intermediate cold storage, and systems that circumvent hydrogen precooling. Proposed concepts should be applicable for use of either gaseous or liquid on-site bulk storage of hydrogen, however on-site hydrogen liquefaction concepts will not be considered for this subtopic.

Phase I of the project is expected to focus on an in-depth analysis of the system or component(s) proposed, refueling protocol efficiency and overall costs. Testing protocols, including safety, should also be established as a part of Phase I. Phase II will focus on prototype development and testing at the laboratory scale.

Questions – Contact: Neha Rustagi, Neha.Rustagi@ee.doe.gov

e. Other

In addition to the specific subtopics listed above, the HFTO invites grant applications in other areas that directly apply to the advancement of polymer electrolyte membrane fuel cells for medium- and heavy-duty vehicle applications, especially in terms of improved efficiency, increased durability, and reduction in cost.

Questions – Contact: Donna Ho, Donna.Ho@ee.doe.gov

References: Subtopic a:

1. Marcinkoski, J., et al. “Hydrogen Class 8 Long Haul Truck Targets.” Program Record, December 12, 2019, https://www.hydrogen.energy.gov/pdfs/19006_hydrogen_class8_long_haul_truck_targets.pdf

2. U.S. Department of Energy. “DOE Launches Two Consortia to Advance Fuel Cell Truck and Electrolyzer R&D.” Million Mile Fuel Cell Truck (M2FCT) consortium announcement, October 8, 2020, https://www.energy.gov/eere/articles/doe-launches-two-consortia-advance-fuel-cell-truck-and-electrolyzer-rd

References: Subtopic c:

1. Li, H., Song, C., Zhang, J. and Zhang, J. “Catalyst Contamination in PEM Fuel Cells.” In: Zhang, J. (eds) PEM Fuel Cells Electrolysis and Catalyst Layers. Springer, London. https://doi.org/10.1007/978-1-84800-936-3_6

2. International Organization for Standardization. “Hydrogen Fuel Quality – Product Specification.” November, 2019, https://www.iso.org/standard/69539.html

3. Society of Automotive Engineers. “Hydrogen Fuel Quality for Fuel Cell Vehicles.” March 18, 2020, https://www.sae.org/standards/content/j2719_202003/

[2] Based on simulations of 7 kg/min fills with a 50-truck fleet comprising 60 kg storage onboard within the Heavy-Duty Refueling Station Analysis Model. In this scenario, the cooling power required is approximately 80 kW.

4. Marcinkoski, J., et al. “Hydrogen Class 8 Long Haul Truck Targets.” U.S. DOE, October 31, 2019, https://www.hydrogen.energy.gov/pdfs/19006_hydrogen_class8_long_haul_truck_targets.pdf

References: Subtopic d:

1. Marcinkoski, J., et al. “Hydrogen Class 8 Long Haul Truck Targets.” U.S. DOE, October 31, 2019, https://www.hydrogen.energy.gov/pdfs/19006_hydrogen_class8_long_haul_truck_targets.pdf

16. SOLAR 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

The Solar Energy Technologies Office (SETO) [1] supports early-stage research and development in the technology areas of photovoltaics (PV), concentrating solar-thermal power, and systems integration with the goal of improving the affordability, performance, and value of solar technologies on the grid. As the primary office within DOE investing in solar power, SETO 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.

The amount of U.S. electricity that is generated by solar technology is increasing. In 2010, less than 0.1% of U.S. electricity generation came from solar energy; in 2020 this fraction is nearly 3%. In some states, solar accounts for almost 20% of all electricity generated [2]. At the same time, the cost of solar electricity is decreasing, driven by global economies of scale, technology innovation, and greater confidence in PV technology. The levelized cost of energy (LCOE) benchmarks and actual power purchase agreement (PPA) prices for utility-scale PV systems have decreased more than 80% since 2010 [3]. These low costs have driven the deployment of over 75 gigawatts direct current (GWDC) of solar capacity in the United States as of the end of 2019 [4]. About half of this capacity was installed after 2016 [5].

SETO advances technologies to use sunlight as an inexhaustible source of clean energy. SETO’s vision is solar energy as a fundamental part of the nation’s energy system and economy by 2050. In order to achieve this vision, the office will continue to work to lower the cost of solar (PV and concentrated solar power) energy and has established a goal to halve the cost of solar energy by 2030 [6]. 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.

Historically, SETO has supported the commercialization of solar innovations through FOAs and other funding programs that relate to one another but have their own unique attributes [7]. Other programs include the American-Made Solar Prize [8], the Incubator topic area in SETO FOAs [9], and the Technology Commercialization Fund [10]. Please read the individual funding opportunities to find the best program for the technology readiness of the proposed technology and to make sure that the application aligns with the program’s goals and objectives.

Applicants are encouraged to take advantage of the Commercialization Assistance Program, which provides funding for commercialization activities in addition to SBIR/STTR research funding. Please read the FOA with more information about this program and how to apply for this additional funding opportunity.

Return to Table of Contents

American-Made Network

The American-Made Network [11] is a great resource for finding commercialization-assistance providers and vendors with specific expertise in the solar space. The Network helps accelerate solar innovations through a diverse and powerful group of entities that includes National Laboratories, energy incubators, investors, prototyping and testing facilities, and other industry partners from across the United States who engage, connect, mentor, and amplify the efforts of small businesses. The Network can help companies solve pressing technology challenges, forge connections, and advance potentially game-changing ideas and innovations.

Application Guidelines

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

- Propose a tightly structured program that includes quantitative technical and business objectives that demonstrate a clear progression in development and are aggressive but achievable;
- 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.

Phase I awards part of this Topic will be made in the form of a grant; SETO anticipates that Phase II awards will be made in the form of a cooperative agreement. In a cooperative agreement, DOE maintains substantial involvement in the definition of the scope, goals, and objectives of the project.

Applicants are strongly encouraged to use the table below to include a summary of objectives they expect to achieve by the end of the Phase I period of performance. A similar table will be required in a Phase II application. DOE has the possibility to negotiate project milestones with entities selected for a Phase II award. The table contains examples of each objective type, to guide applicants while preparing their application. 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. The table should be organized chronologically.

PERFORMANCE METRICS AND SUCCESS VALUES IN THIS TABLE ARE ONLY 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 graphs included in the progress / final report submitted to DOE according to the FARC.	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.

Return to Table of Contents

PERFORMANCE METRICS AND SUCCESS VALUES IN THIS TABLE ARE ONLY 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
2	3	Circuit model curation	> 30 models, of which at least 20 are suitable for testing	Count. 30 realistic and anonymized candidate distribution circuit models identified, of which at least 20 are suitable for detailed testing.	Description of circuit models, load models, impedances, and connectivity characteristics included in the progress / final report submitted to DOE according to the FARC.	Load models, impedances, and connectivity characteristics must be included in the report to assess the feasibility of the proposed circuits.
3	4	Feedback	> 10 potential users	Count. A minimum of 10 potential users of the tool will undergo a demo of the software (in-person or webinar) and provide feedback. Users must provide specific feedback as to the minimum availability and response time they require for their specific use case.	Documentation of feedback and a justified plan to implement or reject recommendations from potential users included in the progress / final report submitted to DOE according to the FARC.	User feedback is a critical part of an iterative development cycle to ensure the solution is useful to potential off-takers.
4	4	Module lifetime	> 30 years	Accelerated testing conducted according to testing procedures listed in IEC 1234.	Raw data and graphs included in the progress / final report submitted to DOE according to the FARC.	IEC 1234 is the industry-used module degradation test.
5	5	Heliostat installed cost	≤ $50/m2	Average expected accuracy range is +20%/-15%.	Cost model with description of assumptions used for input parameters, methodology for the sensitivity analysis, supporting documents used to	Success metrics defined in the FOA.

Return to Table of Contents

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#	Month of completion	Performance Metric	Success Value	Assessment Tool / Method of Measuring Success Value	Verification Process	Metric Justification, Additional Notes
					determine the bill of materials included in the progress / final report submitted to DOE according to the FARC.	
6	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 included in the progress / final report submitted to DOE according to the FARC.	Engaging with a large domestic module manufacturer is essential to show there are interested technology off-takers.
7	6	Simulation validation	Single feeder simulation	Power flows validated on a single realistic distribution feeder in simulation. Phasor tracking shows agreement with expected power flows at every circuit node to better than 5%.	Quantitative simulation results included in the progress / final report submitted to DOE according to the FARC.	5% agreement is required to assess the quality of the simulation tools.
8	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 included in the progress / final report submitted to DOE according to the FARC.	Implications of new platform architecture in the context of new cybersecurity concerns must be investigated and mitigated if necessary.
9	9	Module efficiency	> 25% efficiency	Average, standard deviation. At least 10 modules measured under standard conditions. Standard deviation <	Raw data, graphs, and report from testing facility included in the progress / final report submitted to	The success value was chosen based on initial cost modeling. Efficiency lower than 25% makes this technology not competitive with

PERFORMANCE METRICS AND SUCCESS VALUES IN THIS TABLE ARE ONLY 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% (absolute efficiency).	DOE according to the FARC.	current state of the art.
10	9	Binding letters of intent	2 letters	Count. A minimum of 2 letters of intent from relevant stakeholders committing to fabricate and test a large-scale prototype of this technology.	Letters included in the progress / final report submitted to DOE according to the FARC.	Success of the award will be measured by successful technology transfer to private entities.
11	9	Contract	> 1	Count. At least one agreement with a non-team-member to share data and beta test the solution.	Agreement included in the progress / final report submitted to DOE according to the FARC.	Success of the award will be measured by successful technology transfer to private entities.

NOTE: In addition to the subtopics below, SETO is considering applications in response to Topic 20 - Joint Topic: CABLE through subtopic f: Electrical connections for photovoltaic modules and systems. Applications on technologies related to PV electrical connections will be considered nonresponsive if submitted to this topic (Topic 16, Solar Energy Technologies).

Applications are sought in the following subtopics:

a. TECHNOLOGY TRANSFER OPPORTUNITY: Method for Mechanical Load Testing of Photovoltaic Modules with Concurrently Applied Stressors and Diagnostic Methods

This is a Technology Transfer Opportunity for a non-exclusive license to commercialize a newly developed and PV module testing platform that allows for simultaneous application of multiple stress factors of the natural environment.

Comprehensive design testing of PV modules is challenging. Typically, stresses at levels higher than those occurring in the natural environment are applied to achieve acceleration. These stress factors are usually applied in steady state, with fewer stress factors, or in combinations and sequences that do not reflect real world conditions. Also, stress tests are frequently designed around failure modes in existing designs that have already manifested in the field, limiting our ability to predict the potential occurrence of failures with new PV module materials and designs. Real-world load tests – required for modules in environments in which high wind or snow loading is commonplace – are difficult to replicate because currently used techniques cannot replicate the high frequency module vibration experienced in high winds while also thermally stressing the module, allowing for water ingress, and allowing exposure to light. Current methods for applying mechanical load to a module for mechanical testing obstruct significant amount of light from at least one side of the module whereas open rack systems, especially for bifacial modules, are designed for exposure to light from both faces of the module. While each of the stress factors are frequently applied in isolation, no current test for full size commercial PV modules can replicate the combination of stress factors as occurs in the natural environment in which they have been known unexpectedly fail, in part because of the limitation of commonly used stress tests.

The National Renewable Energy Laboratory (NREL) has developed a PV module testing platform to simultaneously apply multiple stress factors of the natural environment (light, heat, moisture, system voltage, and mechanical stress) to achieve a comprehensive test of module durability. The simulation applies levels corresponding to the extremes of the conditions found in the natural environment using a four-cell mini module platform. We seek the scale up and commercialization of a system for full size modules with these five stress factors, including a system that applies an oscillating mechanical load to the edges of a PV module in such a way so as to avoid obstructing the active cell area. To achieve this, the module can be vibrated at its mounting points so that the interior of the module is rapidly displaced by its own momentum. Avoiding the obstruction of light this way, additional stressors including light, heat, moisture would be simultaneously applied the active area of the module such that they me be monitored by optical or electro-optical means to evaluate any module degradation in-situ. NREL is currently looking for partners to help with prototyping and commercialization of the combined- accelerated stress testing system for the evaluation of durability of full-size commercial PV modules.

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
NREL tracking number: 19-64

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

b. TECHNOLOGY TRANSFER OPPORTUNITY: Nanocomposite Barrier Films for Photovoltaic Applications
This Technology Transfer Opportunity solicits interested companies to license a newly developed and patented thin film coating that can be used as an encapsulant for photovoltaic module assemblies and barrier coating in other photovoltaic applications.

Polymer-clay nanocomposites (PCN) thin film coatings have improved water vapor and oxygen permeability, in addition to improved corrosion resistance, while retaining high transparency, high electrical resistivity, and excellent fire-retardant properties for use as encapsulants for photovoltaic module assemblies and barrier coatings in other photovoltaic applications.

In these unique composite materials, repeated sequential deposition of solutions of clays (vermiculite, montmorillonite, etc.) and solutions of polymers (polyethylenimine, poly(acrylic acid, etc.) layer with complimentary charged functional groups (positive and negative) forms a coating. The coating can be deposited with many various repeating schemes as it is built one layer at a time. Once cured, the microstructure resembles a brick and mortar system where the clay platelets are the “bricks” and the polymer is the ”mortar”. The facile and scalable layer-by-layer processing is applicable to many substrates, from porous and flexible items such as fabrics and foams to hard dense materials such as glass or ceramics.

As an impermeable barrier, the structure dictates a tortuous path for oxygen or water molecules to follow, which decreases the water transmission rate by over an order of magnitude beyond ethyl vinyl acetate (EVA). During a fire, the applied composite coating reduces the heat rate release, and can act as a flame retardant system. In an arcing electrical system, the PCN coating promotes extinguishment and increases time to flame by as much as 300%.

Sandia National Laboratories Information:
Licensing Information: Sandia National Laboratories
Contact: Margaret Gordon, megord@sandia.gov
License type: Non-Exclusive
Patent Status: Active - https://patents.google.com/patent/US10002983B1/
Publication date: 06/19/2018
Filing date: 05/24/2017

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

c. Floating Solar-Powered Aeration Systems

In this subtopic, SETO seeks innovations that can advance the application of floating solar-powered aeration systems (FSAS) to improve water quality.

Aeration is the introduction of air into aquatic systems to support the growth of aerobic bacteria and aquatic life. Facilitating the oxidative decomposition of biological materials, aeration can also remove the gaseous products of decomposition, including ammonia, hydrogen sulfide, methane and carbon dioxide. Many natural systems depend upon aeration to maintain a diversity of animal and plant species, as well as overall health. However, a surplus of nutrients, restricted mixing and flow, or significant depth can deplete dissolved oxygen in aqueous systems [1, 2].

Artificial aeration has been developed to address this issue. As a technology, aeration is generally applied to establish, maintain, or restore sufficient dissolved oxygen to ensure successful remediation and protection of water resources, including natural bodies of water (e.g., rivers, lakes) and artificial ones (e.g., fish farms, lagoons) [2]. Recently, self-powered, autonomous units that combine floating photovoltaics and aeration have been implemented to help restore natural water resources.

Applications should fall within one of the following three broad areas for ecosystem management on water systems:

- FSAS for environmental restoration and protection of natural water systems [1, 2];
- FSAS for sustainable water systems for aquaculture [3];
- FSAS for sustainable waste bio-processing water systems [4].

Applications for FSAS outside these three categories will be considered if they focus on aeration via a floating solar-powered system. Applications should describe aeration parameters such as depth, timing, and rate of aeration; electrical-system specifics such as power requirements, electrical storage, and control systems; and any other subsystems in sufficient detail to explain the innovation.

SETO is particularly interested in applications developing technologies that:

- Reduce operating costs by using FSAS to improve water quality;
- Reduce the balance-of-system costs of an FSAS;

- Improve the effectiveness and operation of FSAS;
- Build synergy between FSAS and other unit operations to add value via enhanced system functionality; and
- Generate an excess of electricity beyond that needed for aeration to provide power for external electrical systems (either floating, submerged, or shore-based).

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

d. Solar Systems Resilient to Weather-related or Cyber Threats

In this subtopic, SETO seeks innovative proposals to improve the ability of solar assets or electronic devices associated with solar energy generation (such as inverters, direct current (DC)-DC optimizers, and smart meters) and systems to quickly recover in response to weather-related or cyber threats [1].

One of SETO's priorities is to enhance the ability of solar energy technologies to contribute to grid reliability and resilience, including the security and resilience of the nation's critical infrastructure. Infrastructure systems, including the electrical grid and solar generation assets, are vulnerable to weather-related threats, cyberattacks, and other disruptive events. Increased asset resilience presents opportunities to maximize operability and energy availability and minimize restoration costs following these occurrences.

Applications to this subtopic may address specific component or system designs that improve survival; improve recovery time; ensure access control, confidentiality, integrity, availability, or non-repudiation of assets; and minimize cost associated with disruptive events. Component or system designs may achieve these goals passively (e.g., via more robust designs or configurations) or actively (e.g., via "hardened" components, including any component that is connected in a smart power systems injection/absorption role).

Applications must include a basic cost-model analysis showing the cost/benefit of the proposed solution in comparison to current state of the art. Proposed solutions should discuss the component(s) being addressed, potential threats that will be deterred, method of integration (especially clarifying if it is part of a traditional PV component for integration at install or a retrofit for a fielded device), how interoperability with other components is considered, and how compromises or attempted compromises are conveyed to the relevant parties. Applications should also identify a possible case use by defining the time to recover the system's full functionalities, and provide substantiated estimates for the capabilities of the proposed approach.

Examples of targets and metrics for hardened solar system performance include, but are not limited to:

- Percent of system operable after a disruptive event (applications should specify type and intensity of the threat);
- Time to full system operability after extreme event (restoration time);
- Reduction in system restoration cost following disruptive event;
- Level of functionality without grid support following extreme event (islanding).

Applications will be considered nonresponsive and declined without external merit review if they do not demonstrate clear innovation compared to the current state of the art, particularly regarding microgrid and/or islanding behaviors.

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

e. Innovation in Solar Aesthetics for Residential Photovoltaic Systems

This subtopic solicits proposals for technologies that improve the aesthetic appeal of photovoltaic systems for use in residential applications.

While the PV market has continued to expand rapidly, the rooftop residential market has not grown at the same pace as the utility PV market, as a percentage of added capacity [1]. A survey of solar installers reported 40% of them consider aesthetics to be key when recommending which panels to install [2]. An NREL survey of potential adopters found that approximately 30% of people stopped considering PV installations due to concerns about aesthetics or the impact on the home's resale value [3]. Another survey, of residential customers, found customers do not find currently available solar products attractive, ranking appearance a priority above reliability but below efficiency and price [4].

At the same time, the installed cost per watt has remained high, mainly owing to the slower reduction in non-hardware costs for this segment of the market. This could create an opportunity where an aesthetically pleasing solar module, even with a slightly higher hardware cost, could unlock new portions of the residential market that are sensitive to appearances.

Specific areas of interest include but are not limited to:

- Innovations that greatly improve the aesthetic appeal of a PV installation
- Innovations that mask the PV installation as some other component of the home or landscaping.

Applications will be considered nonresponsive and declined without external merit review if they do not demonstrate clear innovation compared to the current state of the art, particularly in regard to PV module skins and PV-integrated roof shingles.

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

f. Commercial and Industrial Solar Systems

This subtopic solicits applications for innovative technologies that can reduce the installed cost of commercial and industrial (C&I) solar systems, improve their energy yield, facilitate their installation and grid interconnection, and enable additional value streams from them.

The C&I solar market has historically trailed the utility and residential segments, and while the utility sector was up 89% year over year in the second quarter of 2020, the nonresidential sector was down 14% in the same period. Many barriers exist in C&I solar that drive that discrepancy, but there is an opportunity to develop new technologies that can enhance the value proposition. For example, the enhanced energy yield offered by tracking technology could be a game-changer in the C&I market, with its tight margins and complex transactions. Tracking technology has revolutionized the utility-scale solar sector over the past decade, with 65% of all U.S. utility-scale PV systems using single-axis tracking technology as of the end of 2019 (and 82% of U.S. utility-scale PV systems installed in 2019 using single-axis tracking technology) [1].

Applications developing technologies for solar tracking on commercial rooftops or carports are also encouraged.

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

g. Agricultural Solar Systems

This subtopic seeks proposals for innovative technologies that can reduce the installed cost of streams from agricultural solar systems, improve the systems' energy yield, facilitate their installation and grid interconnection, and enable additional value. Of particular interest are new system designs and technologies that optimize solar and agriculture production, which may include novel mounting and racking designs or site configurations.

Although land requirements for solar energy represent a small percentage of the country (92 GW of solar estimated for 2030, which is estimated to require less than 0.1% of the land in the contiguous United States), the growth in ground-mounted solar can create competition with agricultural land for land use. Co-locating solar PV and agriculture could provide diversified revenue sources and ecological benefits for agricultural enterprises while reducing land-use competition and siting restrictions. Except for growing pollinator habitat at solar facilities, the co-location of solar and agriculture is primarily limited to research sites. There are many opportunities to develop new technologies that enable agricultural production (i.e., crop or livestock production, or pollinator habitat) underneath or around solar energy systems that optimize both energy and agricultural production at co-located sites [1].

Value streams of interest under this subtopic include, but are not limited to, increased agricultural yield and quality of life improvements, such as temperature reduction via shading. Applicants must include a strategy for future work to validate additional benefit/value streams, like crop field studies, for example.

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

h. Components for Gen3 CSP Thermal Transport Systems

In support of DOE's Energy Storage Grand Challenge [1], this subtopic seeks proposals for the design of components for the next generation of Concentrating Solar-Thermal Power (CSP) generation technologies.

CSP technologies can be used to generate electricity by converting energy from sunlight to power a turbine. SETO is developing next generation CSP technologies (Gen3 CSP) which aim to deliver heat to a supercritical carbon dioxide (sCO2)-based turbine at or above 700 °C. The Gen3 CSP program [2] identified several heat transfer media (HTM) that showed promise in meeting SETO's electricity cost goals of $0.05/kWh. The program was then organized by the phase of matter for leading HTM— gas, liquid, or solid. Released in 2017, the Gen3 Roadmap study describes the best understanding of potential Gen3 technologies [3]. Since 2017, additional relevant research and analysis has entered the public domain [4-8].

At a high level, the candidate Gen3 CSP thermal transport systems are based on:

- ***Chloride salt blends***. A mixture of magnesium chloride, sodium chloride, and potassium chloride (MgCl2-NaCl-KCl) is a leading salt-based HTM candidate for Gen3. Major impediments to Gen3 paradigms using this HTM in the receiver include catastrophic corrosion in the presence of oxygen or moisture, low thermal conductivity limiting the maximum thermal flux on the leading nickel alloy receivers, and freeze risk. The Gen3 liquid-phase team has determined that a liquid sodium receiver is ultimately less risky than a chloride salt receiver with technologies presently available, however, this salt remains the leading choice of the Gen3 team to transport energy up and down a tower and to act as the thermal energy storage (TES) medium.
- ***Supercritical fluids***. Supercritical carbon dioxide (sCO2) has been considered as a HTM for the Gen3 gas phase system. Major impediments to Gen3 paradigms using this HTM in the receiver include: high-pressure and low thermal conductivity limiting the maximum allowable flux on nickel alloy

receivers; high parasitic losses in circulation greatly impacted by pressure drop in the receiver; creep and fatigue failure of the receiver; and, a higher receiver outlet temperature needed for additional temperature drops in indirect thermal energy storage systems (such as particle beds).

- ***Particles***. Sand-like particles may avoid many of the issues associated with fluid high temperature systems due to the ability to operate at ambient pressure and with limited corrosion or thermal stability risk. Challenges include: operability limitations; risk of particle degradation with time at temperature; scaling limitations; efficiency of heat exchange in the receiver and primary heater; and general challenges in particle transport and mass flow control.

To further develop Gen3 CSP systems and ensure their feasibility in the market, there is a need to design, build and test Gen3 system components that will be economically viable in future Gen3 plants. Applicants are expected to include the design, feasibility, and cost validation of new or improved components and subsystems during their Phase I application; lab scale testing, and prototype manufacturing of such components is of interest in Phase II applications.

The following are specific components that are of interest for development and desired performance parameters that would be supported under this subtopic:

Components

- Receivers:
  - Thermal efficiency > 90%.
  - Cost < 75 $/kWth (receiver only; excludes tower and piping).
  - Total receiver system cost including tower, piping, and cold salt pump < 150 $/kWth.
  - Lifetime > 10,000 cycles.
  - Applicable to gas, particle, or molten salt operation at >750°C.
- Hot and cold salt pumps:
  - Designed for 720°C operation.
  - Operating power less than 5% of plant annual output. Developers can focus on subcomponents of the pumps and manufacturing processes for these subcomponents such as bearings, impellers, shafts.
- Particle elevators:
  - Designed for 750°C operation.
  - Operating power <5% of plant annual output.
- Thermal energy storage system:
  - Containment design for solid and liquid thermal energy storage at 720°C.
  - Cost target of 15 $/kWth.
  - Energetic efficiency >99%; exergetic efficiency >95%.
- Balance of plant systems:
  - Low cost piping.
  - Low cost pipe and containment insulation for 720°C operation.
  - Design and manufacture of valves and fittings for 720°C operation, including check valves, control valves, gate valves and slide gates for solids.
- Heat exchanger
  - Particle, salt, and gas to sco2 heat exchanger designs sought.
  - Cost target of 150 $/kWth power block energy input.
  - 720°C sCO_2 outlet temperature.
  - 90-95% effectiveness depending on primary media.

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

i. Affordability, Reliability, and Performance of Solar Technologies

This subtopic solicits proposals for solutions that can advance solar energy technologies by lowering cost [1] and facilitate the secure integration into the Nation's energy grid. Applications must fall within one of these areas: advanced solar systems integration technologies, concentrating solar thermal power technologies, or photovoltaic technologies.

Specific areas of interest include, but are not limited to:

- Technologies that reduce the manufacturing costs of solar energy system components or subcomponents to boost domestic energy manufacturing and increase U.S. manufacturing competitiveness;
- Technologies that can measure, validate, or increase outdoor PV system reliability;
- Technologies enhancing the ability of solar energy systems to contribute to grid reliability, resiliency, and security;
- Technologies or solutions that reduce the balance-of-system costs of a PV system;
- Technologies that build on other SETO programs and/or leverage results and infrastructure developed through these programs [2]. In the past 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.

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 solar generation on the grid.

Applications will be considered nonresponsive and declined without external merit review if they are not based on sound scientific principles, are within the scope of any other of the subtopic listed under the Solar Energy Technologies topic, or do any of the following:

- Focus exclusively on HVAC or water heating applications;
- Propose development of concentrated PV or solar spectrum splitting technologies;
- Propose development of technologies with very low possibility of being manufactured domestically at a competitive cost (e.g., PV modules based on copper zinc tin sulfide (CZTS) or amorphous silicon thin films; technologies assuming incorporation of functional materials, such as quantum dots or luminescent solar concentrators);
- Propose technologies to improve the shade tolerance of PV modules;
- Business plans or proofs of concept that do not include documentation supporting their necessity or benefit. 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 support 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;

- 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;
- Propose development of ideas or technologies that have already received federal support for the same technology at the same technology readiness level.

This subtopic seeks to assist independent, growing small businesses that will successfully bring a new technology to 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 that requires continued government support.

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

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Return to Table of Contents

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17. 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

EERE's Vehicle Technologies Office (VTO) provides low cost, secure, and clean energy technologies to move people and goods across America. VTO supports research, development (R&D), and deployment of efficient and sustainable transportation technologies that will improve energy efficiency, fuel economy, and enable America to use less petroleum. These technologies, which include advanced batteries and electric drive systems, lightweight materials, advanced combustion engines, alternative fuels, as well as energy efficient mobility systems, will increase America's energy security, economic vitality, and quality of life.

All SBIR proposals submitted to VTO 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 Refer to the VTO website for currently funded projects (https://www.energy.gov/eere/vehicles/vehicle-technologies-office).

Grant applications are sought only in the following subtopics:

a. Electric Drive Vehicle Batteries

This subtopic seeks applications for research to develop electrochemical energy storage technologies that support commercialization of micro, mild, and full Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Electric Vehicles (EVs).

Some specific improvements of interest to be considered in this subtopic include the following:

- New low-cost materials for HEVs, PHEVs, and EVs.
- Alternatives to or recycling technologies for critical materials [1] for energy storage.
- 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 Solid Electrolyte Interphase 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 in electric drive vehicle batteries 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 DOE and the U.S. 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 200 milliamp-hours (mAh) in size while Phase II technologies should be demonstrated in full cells greater than 2 Ah.
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.

Research sought through this subtopic supports DOE's Energy Storage Grand Challenge, a comprehensive program to accelerate the development, commercialization, and utilization of next-generation energy storage technologies and sustain American global leadership in energy storage. In addition, the subtopic supports for the objectives of the Critical Minerals Initiative to reduce both the costs of critical materials and the environmental impacts of production to create a sustainable critical-materials supply chain in the United States.

Questions – Contact: Simon Thompson, Simon.Thompson@ee.doe.gov

b. Motor Designs without Critical Materials for Electric Drive Vehicles

In support of DOE's Critical Minerals Initiative, this subtopic seeks to address the challenges of lower cost motors with higher power density for vehicle traction while reducing critical materials3 use.

Currently, critical materials [1] like neodymium and dysprosium are vital to manufacturing magnets used in most electric motors powering electric vehicles on the road today. Demand for these resources continues to grow, and in response to Executive Order 13817, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals[2], DOE is leading the way in developing alternative technologies that do not rely on these critical materials.
In addition, focused exploratory research for electric motors is needed to meet the cost and size targets described in the U.S. DRIVE partnership Electrical and Electronics Technical Team (EETT) Roadmap.[3]

To achieve these goals, VTO and its partners are already examining many research avenues, including: lower-cost permanent magnets and magnetic materials; reduced rare-earth magnet motors; non-permanent magnet motor designs; and improving electric motor thermal management, performance and reliability.

Applications to this subtopic should describe technical approaches for electric motor designs that aim to meet EETT targets while significantly reducing critical materials content. These motor designs should differ significantly from current or previous DOE research projects, and performance claims or benefits need to be supported by sufficient mathematical modeling and data analysis.

Applicants should show a relationship to, and demonstrate and understanding of, automotive application requirements and environments. Projects should aim to design and simulate a > 80 kW peak capable motor in Phase I, with plans to prototype at least one motor in Phase II.

[3] As defined in Executive Order 13817, a critical mineral is "a mineral identified by the Secretary of the Interior [pursuant to the Executive Order] to be (i) a non-fuel mineral or mineral material essential to the economic and national security of the United States, (ii) the supply chain of which is vulnerable to disruption, and (iii) that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for our economy or our national security."

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

c. Game Changing Technologies for Polymer Composites

In support of DOE's Plastics Innovation Challenge, this subtopic encourages the submission of proposals for innovations in polymer composites such as carbon fiber reinforced polymer composites that have the potential to provide the most significant weight savings (up to 60-70%), while offering high specific strength, high specific stiffness, and excellent chemical/corrosion resistance which are important in a vehicle operational environment. Enabling the use of lightweight materials across the automotive industry through the development of novel materials, composite preforms and intermediates, manufacturing processes, and components for high-volume, high-performance, and affordable polymer composite vehicle applications is a key enabler for increasing fuel economy and reducing the environmental impact of vehicles.

Areas of interest within this subtopic are as follows:

1. **Multiscale reinforced lightweight polymer composites**: Polymer composites often rely on employing reinforcements such as micro- or nano-fillers in a relatively soft matrix. Simply using a single type of reinforcement (either micro- or nano-fillers) in polymer composites has almost achieved its reinforcing limit. Multiscale micro/nano hybrid reinforcements are anticipated to achieve exceptional reinforcing effects, which are beyond the reach of a single type of reinforcement. Such hierarchical hybrid fillers are expected to enhance the filler/matrix interfacial load transfer. However, simultaneously adding both micro- and nano-reinforcements in a polymer matrix material remains challenging since nano-fillers tend to loosely adhere (agglomerate) onto micro-fillers, decreasing their reinforcing effects [1].

Areas of interest:

- Technologies to achieve multiscale (both micro- and nanoscale) reinforcing effects simultaneously in the polymer matrix.
- Development of new kinds of fillers with both micro- and nano-characteristics enabling multiscale reinforcing mechanisms in polymer composites.

2. **Nano-additive enabled upcycling of polymer composites**: Polymer composite vehicle structures/parts are required to be recycled for reuse. Converting polymer composites into a value-added product will significantly reduce the amount of plastic that becomes landfill or environmental pollution. The recycled composites often exhibit degradation in both properties and functionalities. Upcycling is needed to restore the recycled composites to achieve the same or even superior properties and functionalities over the pristine polymer composite counterparts [2]. Nano-additives are anticipated to offer an intriguing upcycling opportunity through reinforcing matrix and/or tailoring filler/matrix interface to achieve a higher load-transfer efficiency.

Areas of interest:

- Technologies to upcycle polymer composites by adding low-cost nano-fillers in recycled composites.
- Development of low-cost nano-additives capable of restoring recycled composites to achieve the same or even superior properties and functionalities over the pristine polymer composite counterparts.

Proposals must tie in with structural polymer composites that have advantages of low cost, lightweight, and high performance for vehicle applications. Any proposals using above technologies to develop or improve battery materials performance will not be considered.

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

d. Reliable, Durable, Low-Cost Sensors for Advanced Combustion and Emission Control Strategies

This subtopic solicits proposals to develop sensors for engine combustion and after treatment systems that offer a significant decrease in cost while demonstrating durability, as well as improved speed and accuracy that enable new combustion strategies.

Advanced combustion engines that increase fuel economy while meeting increasingly stringent emission regulations will require innovative control strategies. Such control strategies need a variety of accurate and timely inputs. Sensors which measure important inputs like temperature, pressure, fuel-air ratio, fuel quality, and piston and valve position, as well as reliably detect pollutants at all operating conditions would be installed on future engines and used for combustion control and active feedback. While various sensor options are currently available, significant reductions in cost and increased durability are needed to be widely implemented. In some cases, improvements in speed and accuracy of sensor measurements are desired to enable real-time adjustments of engine operation that would facilitate further efficiency improvements.

Combustion strategies that operate fuel-lean offer superior fuel efficiency, but require complex exhaust gas after treatment systems, including particulate filters and selective catalytic reduction (SCR) catalysts using injected urea solution, to comply with emission regulations. Currently, back pressure sensors are employed in conjunction with control maps to identify when regeneration (soot oxidation) of particulate filters is needed, but more advanced sensors may enable reducing the regeneration frequency and/or shortening the length of the process (reducing fuel penalty). Real-time sensors for direct measurement of exhaust oxides of nitrogen (NOx) and particulate matter (PM) and for ammonia (NH3), are lacking. Adoption of low NOx and PM regulation will further challenge measurement of these ultra-low pollutants.

Applications must demonstrate:

- An understanding of the current state-of-the-art (SOA) in automotive sensors.
- Why the proposed technology represents significant improvement in the SOA with respect to cost, accuracy, durability, or other important parameters.
- Evidence, or a plan to demonstrate, that the sensor will work reliably for the typical lifetime of the vehicle.
- Evidence that the proposed sensor technology once installed in engines and after treatment systems will facilitate fuel efficiency improvements.
- Evidence that the sensor is likely to be successfully installed on a modern, production automotive engine in Phase II.

Questions – Contact: Michael Weismiller, michael.weismiller@ee.doe.gov

References: Subtopic a:

1. “Energy Storage System Goals.” United States Council for Automotive Research, LLC., 2020, http://www.uscar.org/guest/article_view.php?articles_id=85

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

References: Subtopic b:

1. Department of the Interior. "Final List of Critical Minerals 2018," 83 Fed. Reg. 23295; 2018 https://www.federalregister.gov/documents/2018/05/18/2018-10667/final-list-of-critical-minerals-2018

2. Executive Office of the President. "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals." Federal Register, White House, December 2017, https://www.federalregister.gov/documents/2017/12/26/2017-27899/a-federal-strategy-to-ensure-secure-and-reliable-supplies-of-critical-minerals

3. USCAR. "Electrical and Electronics Technical Team Roadmap." USDrive, October 2017, https://www.energy.gov/sites/prod/files/2017/11/f39/EETT%20Roadmap%2010-27-17.pdf

References: Subtopic c:

1. Song, N., Zhang, Y., Gao, Z., Li, X. "Bioinspired, Multiscale Reinforced Composites with Exceptionally High Strength and Toughness." Nano Letters, Vol. 18, 5812-5820, 2018, https://pubs.acs.org/doi/abs/10.1021/acs.nanolett.8b02459

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18. WATER 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

EERE's Water Power Technologies Office (WPTO) (http://energy.gov/eere/water/water-power-program) works with national laboratories, industry, universities, and other federal agencies to conduct research and development activities through competitively selected, directly funded, and cost-shared projects. WPTO pioneers research and development efforts in both marine and hydrokinetic (MHK) and hydropower technologies to improve performance, lower cost and ultimately support the United States' ability to sustainably meet its growing energy demand. MHK technologies capture energy from waves, tides, ocean, and river currents, as well as from ocean thermal gradients. 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.

For FY 2021 solicitation, WPTO is seeking applications for MHK technologies only. MHK technologies are at an early stage of development because of the fundamental challenges of generating power from dynamic, low-velocity, and high-density waves and currents, while surviving in corrosive marine environments. These challenges are intensified by high costs and lengthy permitting processes associated with in-water testing. To achieve the mission and help to realize the vision, the MHK Program must support research and development (R&D) efforts that lead to significant reductions in the cost of MHK energy that enable industry to be competitive in U.S. electricity markets.

Applications to ether subtopic 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.

Note: In addition to the sub-topics (a) and (b) below, WPTO is supporting subtopic e under Topic 20 – Joint Topic: CABLE Materials and Applications entitled Electric Systems—Generators and Motors.

Grant applications are sought only in the following subtopics:

a. Co-Development of Marine Energy Technology at Smaller Scales (CMETTS)

This subtopic seeks proposals for the development and design of new marine energy prototypes specific to the needs of an identified end user in the blue economy.

CMETSS seeks to advance near-term marine energy opportunities in the blue economy by supporting the development of solutions tightly coupled to end-user needs. Specifically, this subtopic seeks to support the development of industry projects that link marine energy technologies together with blue economy energy end users to co-develop solutions specific to energy constraints.

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 new pathways for sustainable economic development.

Recognizing this opportunity and the potential for marine energy to ease energy constraints, WPTO released a report in 2019 titled “Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets” [1]. The report describes eight non-grid applications where marine energy could provide consistent, reliable power. This report serves 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. Upfront engagement with end-users and coastal communities is essential to successful technology integration to achieve design goals. Moreover, applications of marine energy 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 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.

In FY 2021, applicants to this subtopic are strongly encouraged to explore new co-development topics that are not duplicative with other efforts underway with WPTO such as the Ocean Observing Prize DEVELOP Competition [2] focused on wave energy powered rechargeable autonomous underwater vehicles and solutions fit for the Waves to Water Prize [3] developing wave energy powered desalination suited for disaster relief and recovery.

Areas of interest including and beyond applications cited in the Powering the Blue Economy report can include, but are not limited to, lightweight devices, short duration deployments, disposable materials, or other novel and innovative features.

Applicants must identify and demonstrate at least one end-user whom they will work with during the project. WPTO encourages engaging with end users to understand their power requirements and the functional requirements required. As an example, of the type of engagements the program has done with end-users, please see the published “Enabling Power at Sea: Opportunities for Expanded Ocean Observations through Marine Renewable Energy Integration” [4]. The identified end-use partner(s) may be listed as project participant(s). Applicants must demonstrate that a prototype, with an identified partner, can be designed and built with funds provided in Phase II.

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 solicitation, the solution should demonstrate potential for applicability for other applications or purposes.

It is expected that Phase I work would be centered on end-user and customer discovery for the proposed concept; collecting end-user or customer requirements; converting collected customer requirements into system design requirements; using those design requirements to inform preliminary prototype design; and performing preliminary proof-of-concept testing or modeling of system components. One of the deliverables for Phase I will include a table of design specifications for the system and how each relates to a customer need. In Phase II, the awardee(s) will refine system designs based on the findings from Phase I and proceed to build a functioning prototype to be tested and/or deployed. Phase II awardees must also present a detailed plan for technology commercialization.

For Phase I proposals, competitive applicants should demonstrate knowledge, experience, and/or capabilities in developing marine technologies and include the following in their proposals:

- A preliminary design of the proposed system with estimated physical dimensions;
- A clear description on how the system would function;
- The end-user or customers that will be engaged during the project;
- Identification of the marine energy resource that would be utilized;
- The method or methods by which customer needs will be converted into design requirements or specifications, for example: Quality Function Deployment, Design Structure Matrix, Kano Method, or Axiomatic Design;
- Identification and description of the proposed performance metrics which will be used to assess the system in comparison to incumbent technologies, such as levelized cost of energy, levelized avoided cost of energy, or other similar metrics. Please refer to “Existing Ocean Energy Performance Metrics” for examples [5];
- A description of the intended deployment location(s) and the available energy in the chosen marine energy resource, including identification of any 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

b. Low-Cost, User-Friendly Monitoring Tools for MHK Sites

This subtopic supports the development of novel methods for environmental monitoring and/or resource characterization at MHK sites that are very low cost and very easy to use. This may include hardware/sensing packages, methodologies, and/or software/analysis tools.

Uncertainty regarding environmental impacts of MHK devices has resulted in extensive baseline and post installation monitoring requirements, which can be difficult and expensive to fulfil with existing environmental monitoring technologies. Many existing environmental monitoring technologies are not designed for or validated for use in locations relevant to MHK. Meanwhile, monitoring efforts for resource characterization face similar challenges, especially for small scale, distributed MHK applications. Additionally, to detect what are anticipated to be rare extreme events, most monitoring systems produce large data streams which must then be extensively and complexly processed and analyzed. Previous research and development have made substantial improvements in the technical performance of monitoring technologies in MHK environments, yet the costs associated with data collection are still prohibitive, and analysis often needs to be performed by a technical specialist.

Areas of particular interest include, but are not limited to:

- Detection of collision of fish, marine mammals, or diving seabirds with tidal turbines.
- Collision of marine animals with tidal turbines. While this is believed to be a rare event and there have been limited observations of organisms being struck by or colliding with tidal turbines, there remains a limited ability to observe animals near a turbine, and collision occurrence rates and outcomes have not been well established.
- Measurement of baseline and changes in noise, currents, or wave climate.
- Identification of baseline conditions for ambient noise and physical systems such as currents and/or the wave climate. As part of permitting, MHK projects are often required to identify such baseline conditions and quantify if and how installation and operation of their device alters the soundscape and physical systems.
- Leveraging or modifying existing MHK device performance monitoring technology for environmental monitoring.
- A possible strategy for lowering cost, complexity, and effort is to harness existing monitoring and adapt it for other needs. If a variable, e.g. noise, is being monitored for device performance, perhaps some modifications could be made such that data collected for device monitoring could additionally serve site monitoring, or vice versa.
- Environmental monitoring or resource characterization approaches specifically suited to small scale, distributed MHK, supporting Powering the Blue Economy initiatives.
- Low-cost, user-friendly solutions for MHK monitoring. Smaller scale projects often have smaller scale budgets and personnel. Ideally solutions would apply or be adaptable to multiple project types and/or geographic regions, although especially creative and impactful solutions with a narrow focus could also be of interest.

A key consideration for this topic area is the creation of very low cost and very user-friendly monitoring tools and methodologies. Proposed systems should strive to reduce the cost of instrumentation and data collection by 50 percent as compared to current technologies and methodologies. Additionally, any tools or methodologies should be executable by personnel with basic training, and output data should be in a format and units that are readily understandable by MHK project teams and regulators, and directly address key environmental and/or resource questions.

For Phase I applicants will:

- Produce a final design of the proposed technology or methodology;
- Produce a refined drawing or schematic of the proposed system;
- Develop a description of the cost associated with current technologies used for specified data collection and cost target for proposed technology at commercialization;
- Provide detailed description of the level of training needed to operate the monitoring instrumentation and analyze data;
- Provide a description and/or example of the final data output created by the monitoring technology and discuss how the data output addresses the needs of the target audiences;
- Provide details of work to be performed in Phase 1 including required resources and technical performance targets;
- Fabrication of a working prototype (for new methodologies and adaptations of existing technologies); Fabrication of a key component (for new technologies and new instruments)
- Perform proof of concept testing of prototype or component in a lab or tank setting.

Phase II will include, but is not limited to:

- Fabrication of a working prototype;
- Rigorous testing of the technology in a relevant MHK environment;
- 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 monitoring technologies for the marine environment and include the following in their application:

- A preliminary design of the proposed system and a clear description on how the system would operate;
- A drawing or schematic of the proposed system;
- A cost estimate for the proposed system and comparison to costs for existing state of the art technologies;
- An estimate of the level of training needed to operate the proposed monitoring instrumentation and analyze resulting data;
- A conceptualized or actual example of the proposed output data;
- Team members or external advisors with essential expertise relating to both MHK and environmental monitoring / resource characterization

Questions – Contact: Rajesh Dham, Rajesh.Dham@EE.Doe.Gov

References:

1. Copping, A.E. and Hemery, L.G., editors. "OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World." Report for Ocean Energy Systems (OES). DOI: 10.2172/1632878, 2020, https://tethys.pnnl.gov/publications/state-of-the-science-2020

Return to Table of Contents

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References: Subtopic a:

1. LiVecchi, A., A. Copping, D. Jenne, A. Gorton, R. Preus, G. Gill, R. Robichaud, R. Green, S. Geerlofs, S. Gore, D. Hume, W. McShane, C. Schmaus, H. Spence. "Powering the Blue Economy; Exploring Opportunities for Marine Renewable Energy in Maritime Markets." U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Washington, D.C., 2019, https://www.energy.gov/eere/water/downloads/powering-blue-economy-report

2. "DEVELOP Competition: Develop a Marine Energy Powered System." AmericanMade, NREL, 2020, https://americanmadechallenges.org/oceanobserving/develop.html

3. "Waves to Water Prize." AmericanMade, NREL, 2020, https://americanmadechallenges.org/wavestowater/

4. Green, R., Copping, A., Cavagnaro, R.J., Rose, D., Overhus, D., and Jenne, D. "Enabling Power at Sea: Opportunities for Expanded Ocean Observations through Marine Renewable Energy Integration." OCEANS 2019 MTS/IEEE SEATTLE, Seattle, WA, USA, 2019, pp. 1-7, doi: 10.23919/OCEANS40490.2019.8962706. https://americanmadechallenges.org/oceanobserving/enabling_power_at_sea.html

5. "Existing Ocean Energy Performance Metrics." (report originally released as a part of a public Request for Information) https://eere-exchange.energy.gov/FileContent.aspx?FileID=89a224a1-6062-4567-a52d-66ddca0aa158

19. WIND 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

EERE's Wind Energy Technologies Office (WETO) (https://energy.gov/eere/wind) drives innovation through research, development, and testing of advanced wind energy technologies. WETO plans and executes a diversified portfolio of research and development to advance technologies for offshore, land-based, and distributed wind energy, as well as its integration with the electric grid. WETO also supports research to understand wind-related siting and environmental challenges. WETO's R&D program pursues three overarching objectives: (a) reduce the cost of wind energy for all wind applications; (b) enable the integration of substantial amounts of wind energy reliably and resiliently into the dynamic and rapidly evolving national energy system, including integrated systems with other renewable energy and energy storage; and (c) create siting and environmental solutions to reduce environmental impacts and facilitate responsible wind energy development. WETO invests in both land-based and offshore wind power at the utility scale as well as systems on the distribution side and focuses on novel research not being undertaken by the U.S. wind industry due to perceived cost, risk, or focus on near-term investment returns.

Wind energy is an important part of the U.S. energy mix. In 2020, there are over 100 gigawatts (GW) of land-based, utility-scale wind installed across 41 states [7], supplying seven percent of U.S. electricity supply [4].

The U.S. has over 85,000 wind turbines in distributed wind applications across 50 states [2]. A nascent offshore wind industry is beginning to develop—driven by federal offshore wind lease auctions, complementary state policies, technology innovation, and falling wind turbine prices—but challenged by unique characteristics of U.S. waters. While utility-scale land-based wind technology is relatively mature, the phase out of the Production Tax Credit in 2020 highlights the importance of continued research and innovation to reduce costs further, so that wind energy can compete and add value to the grid on an unsubsidized basis. Additionally, many remaining sites where wind could be deployed are constrained by an array of environmental and siting concerns. Finally, wind energy's growth has brought attention to the need for advanced technology and controls to support grid resilience and integration of wind with other energy technologies.

WETO aims to advance scientific knowledge and technological innovation to enable clean, low-cost wind energy options nationwide. With continued research and technology innovation to drive down wind energy costs and overcome grid integration, environmental and siting, and workforce development challenges, wind energy has the potential to serve as a key building block of an affordable, reliable, and secure energy future.

Applications may submit to any one of the subtopics listed but all applications must:

- Propose a tightly structured program including technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative and capture potential cost reductions anticipated as a result of the award supported by a clear, literature-based articulation of the baseline and quantitative success metrics, where feasible.
- Include projections for price and/or performance improvements that are tied to a baseline (i.e. DOE Wind Vision [9] 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 expressing how the technical advancements will advance the state of the art.
- Include a preliminary cost analysis and justify all performance claims with theoretical predictions and/or relevant experimental data.
- Include a strong justification of the need for such technical advancements from the perspective of wind research and development, and energy siting and permitting. Where applicable, proposals should demonstrate interest from wind energy original equipment manufacturers or owner/operators regarding potential use of the technologies or where the end user is a regulatory body, interest and support of that body in the products of the research project should also be identified.

Applicants are encouraged, but not required, to describe how the award will foster participation by underrepresented group members including, but not limited to, women or socially or economically disadvantaged persons within the applicant's technology development team, including recruiting, hiring, and training staff to help lead the SBIR/STTR research effort.

Grant applications are sought only in the following subtopics:

a. Technical Solutions to Offshore and Land-Based Wind Siting and Environmental Challenges

This subtopic aims to support technical solutions to offshore and land-based wind siting challenges including impacts on wildlife, radar systems, wind farm neighbors, and other human activities [5, 6]. Technological improvements funded under this topic may be focused on advancements to software, instrumentation, or combined hardware/software systems.

If validation of technologies at a wind turbine or wind farm is a part of the scope of the Phase I effort, a willing host site must be identified in the letter of intent, and a letter of commitment must be provided in the full proposal. Additionally, if access to wind farm data is needed for successful Phase I completion, confirmation of access to that data should be noted in the letter of intent, and a letter of commitment must be provided in the full proposal.

Specific areas of interest include, but are not limited to:

- Technologies aimed at increasing efficacy and/or reducing the cost of environmental impact monitoring or impact minimization for land-based or offshore wind, with an emphasis on novel approaches or tools.
- Technologies aimed at evaluating or reducing impacts of land-based or offshore wind energy development on wind farm neighbors. For offshore wind this includes tools aimed at evaluating or minimizing impacts on coastal communities, historic properties and settings, cultural landscapes, and co-users of ocean space.

Questions – Contact: Jocelyn Brown-Saracino, Jocelyn.Brown-Saracino@EE.Doe.Gov

b. Distributed Wind Technology-Compatible Power Converters for Grid-Connected and Isolated Distributed Energy Systems

This subtopic solicits proposals to develop power converter technologies compatible with distributed wind and wind-hybrid distributed energy systems.

Distributed wind systems are those that use wind energy technology as a distributed energy resource (DER) to support local loads and/or operation of micro- and distribution grids. The lack of advanced power converter technologies that are designed for wind and wind-hybrid distributed energy systems has been identified as a technology gap. Wind-compatible power converters also provide an opportunity for industry collaboration, potential cost savings, and increased power performance with grid support capabilities [2]. Though the expanding market for solar power converters has resulted in technical advancements for solar PV, significant differences in the technical requirements between distributed wind and solar technologies make them suboptimal for use with distributed wind applications. In addition to advanced power converters for standalone distributed wind systems, advanced power converters for wind-hybrid – wind, solar, storage – distributed energy systems are also needed.

Applicants are asked to address the tradeoff between developing turbine controls with power conversion in one combined system compared to physically separating these functions. The latter may be achieved, for example, by pairing the power converter with a wind interface device that has turbine control functions, including command of inverter power output. In addition, applicants should consider the modularity and scalability of their proposed technology to serve a range of turbine sizes and market applications. The envisioned technology is an IEEE 1547-2018-compliant power converter designed for a range wind turbine sizes up to 500 kW in rated capacity, either in standalone applications or in hybrid systems with solar, storage, or other DERs. As part of the project, the applicant must demonstrate that the proposed technology will meet the IEEE 1547-2018 standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces [1].

Questions – Contact: Patrick Gilman, Patrick.Gilman@ee.doe.gov

c. TECHNOLOGY TRANSFER OPPORTUNITY: Wind Turbine Blade Design for Small Wakes

This is a Technology Transfer Opportunity to license and commercialize a wind turbine blade technology developed and patented by DOE's Sandia National Laboratories (SNL). The small wake rotor design patent (US Patent 10,400,743) describes a wind turbine blade design that has a less stable wake than the typical maximum efficiency aerodynamic design. By slightly changing the axial induction, an important aerodynamic performance parameter of a wind turbine, the wind in the rotor wake recovers to the freestream airspeed more quickly.

Wind turbine blades that are designed to create wakes that dissipate more rapidly have the potential to reduce down-turbine turbulence and concomitant wake effects on other turbines. This can reduce capital costs for commercial wind development by allowing wind turbines to be spaced closer together and reducing the power production losses from the wake effects. This, in turn, could potentially reduce the land or sea footprint of a wind plant by as much as half, with additional spillover benefits from reducing balance-of-plant costs. A blade design recently patented by SNL creates a faster-mixing wake that can advance these goals. The new blade technology could be applied to new wind projects, and to repowering of older wind farms to reduce array losses and increase Annual Energy Production. The repower market is expected to be $25 billion through 2030 [3]. This topic area seeks proposals from entities interested in licensing this innovative technology and advancing its transfer to the commercial market.

Licensing Information:
Sandia National Laboratories
For business/partnership inquiries.
Debi Hudgens, PhD, MBA, CLP
Licensing Executive
Tel: 505-284-1596
Email: dhudgen@sandia.gov
Patent: USPTO 10,400,743 http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=10,400,743.PN.&OS=PN/10,400,743&RS=PN
Sandia tracking number: 17139
This patent is available for either exclusive ("period of restraint") or non-exclusive.
https://ip.sandia.gov/

Questions – Contact: Ben Hallissy, Benjamin.Hallissy@ee.doe.gov

References:

1. "1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces." IEEE SA, February 2018, https://standards.ieee.org/standard/1547-2018.html

2. Orrell, A., Preziuso, D., Morris, S., and J. Homer. "2019 Distributed Wind Data Summary." Pacific Northwest National Laboratory. August 2020, https://www.pnnl.gov/sites/default/files/media/file/2019%20Distributed%20Wind%20Data%20Summary-10Aug20.pdf

3. Sullivan, K., "Wind program patent breathes new life into turbine siting." Sandia National Lab, October 2019, https://energy.sandia.gov/wind-program-patent-breathes-new-life-into-turbine-siting/

4. U.S. DOE Energy Information Administration. "Electricity Data, Form EIA-861M." https://www.eia.gov/electricity/data/eia861m/

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

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

7. Wiser, R., M. Bolinger, et al. "Wind Energy Technology Data Update: 2020 Edition." Lawrence Berkeley National Laboratory. August 2020, https://emp.lbl.gov/publications/wind-energy-technology-data-update

20. JOINT TOPIC: CABLE MATERIALS AND APPLICATIONS

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 objectives of the Conductivity-enhanced materials for Affordable, Breakthrough Leapfrog Electric and Thermal Applications (CABLE): Materials and Applications topic are 1) to transfer technology for the fabrication of breakthrough CABLE enhanced conductivity materials and 2) to support leapfrog applications in the design and use of enhanced conductivity materials that will make the performance improvements and energy savings of these applications more affordable.

This joint topic is a collaboration among the following EERE Technology Offices: Advanced Manufacturing, Building Technologies, Geothermal Energy Technologies, Solar Energy Technologies, and Vehicle Technologies as well as the DOE Office of Electricity [1]. Please refer to each office's specific topics for more information about each office.

The use of electricity in the U.S. and worldwide is currently undergoing multiple paradigms shifts in how electricity is generated, delivered, and consumed [2, 3]. There is a critical need for advances in the materials and means by which electricity is translated from generation to use. The demand for CABLE materials and applications are increasing as sectors become increasingly electrified [4]. In addition, there is an urgent need to upgrade electric systems for greater grid reliability because of increasing renewables and distributed energy resources (DERs), and resilience from evolving threats such as cyber-attacks and extreme weather offers a once in a lifetime window of opportunity to upgrade the fundamental materials and applications that support it.

While DOE has funded research on high conductivity materials before, the comprehensive CABLE approach mandates that a breakthrough in electrical or thermal conductivity be balanced with maintenance of other properties needed for applications above a certain minimum value, with minimum standards described in the application specific subtopics below. Furthermore, the CABLE material and its applications must be sufficiently broad and affordable that it enables leapfrogging international competitors and fostering a host of new manufacturing industries to make higher performing materials and the products—everything from transmission and electric vehicle (EV) cables to solar cells—enabled by them.

Return to Table of Contents

This topic supports the objectives of the Energy Storage Grand Challenge, Grid Modernization Initiative, and DOE's support for Advanced Manufacturing as part of its support for to advance the Industries of the Future. Advancements in CABLE materials also support the objectives of the Critical Minerals Initiative.

This topic comprises two distinct, complementary focuses critical to achieve the CABLE objectives.

CABLE materials innovations are the subject of subtopic a) where enhancing conductivity—a "breakthrough, leapfrog" improvement compared to state of the art—must be balanced by meeting all applicable minimum standards for future commercialization of applications (including subtopics b-h). Note that the nano-carbon infusion approach of subtopic a is only one of many promising approaches (many of which also involve the use of critical materials) to make CABLE materials [5, 6, 7, 8,9]. Proposals for research on approaches other than that in subtopic a) are not, however, being sought under this Topic at this time.

CABLE applications (subtopics b-h) should include enhanced conductivity materials (from subtopic a) or other new materials [5 ,6, 7, 8] that meet or exceed metrics specified for each application and to the current state of the art. Even though these applications appear prosaic where substantial R&D effort has been made previously, the CABLE applications listed below, all have the potential to be Breakthrough and Leapfrog because for the first time the research includes re-designing for enhanced conductivity material—something never done before—and exploring the manufacturing and regulatory barriers involved in the use of such materials in pervasive applications.

Enhanced conductivity materials NOT of interest (or applications that rely on them) include:

- Standard superconducting materials;
- High-temperature superconducting materials; and
- Primarily magnetic materials;
- Proposals that focus on these materials will be deemed nonresponsive to this topic.

All proposals to this topic must:

- Propose a tightly structured program which includes clear, CABLE-relevant technical milestones/ timeline that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Provide evidence that the proposer has relevant CABLE and/or OE/EERE experience and capability;
- Clearly define metrics and expected deliverables;
- Explain applications of project output and potential for future commercialization;
- 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;
- Include an energy savings impact and impact grid 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. TECHNOLOGY TRANSFER OPPORTUNITY: Metal-carbon composition and composites manufacturing (CABLE)

This subtopic is the only one in this topic to focus on the conductivity enhanced materials part of the CABLE effort. This subtopic seeks proposals to commercialize the innovation in CABLE materials manufacturing presented in the May 2020 patent and related patent applications from Argonne National Laboratory listed below.

The patent solves one of the technical problems for manufacturing high purity, oxygen-free metal-carbon composites with an electric current. These carbon-infused "covetic" metal alloys might lead to significant energy savings and performance improvements in various applications (e.g., high-voltage electrical transmission, electrical motors and generators, advanced heat exchangers, electrodes for fuel cells, batteries, supercapacitors, and for thermal management in micro- and power electronics). This fabrication method allows precise control of the composition of the covetic material to be produced. The method described herein also can be applied to produce multi-element-carbon composites within a metal or alloy matrix, including high melting temperature materials such as ceramic particles or prefabricated nano- or micro-structures, such as carbon nanotubes or graphene compounds. The covetic reaction between metal and carbon takes place under the influence of flowing electrons through the melted metal-carbon precursor. This process posited to create strong bonding between nanocarbon structure and the metal elements in the melt.

The 2019 patent application is for the initial version of the method to make covetic metal-nanostructured carbon composites or compositions. The method comprises the introduction of carbon into a molten metal in a heated reactor under low oxygen partial pressure, and the passing of an electric current through the molten metal. After heating the covetic material is recovered from the reactor.

The 2020 patent application is for a method for preparing a covetic, nanocarbon-infused, metal composite material by heating a stirring molten mixture of a conducting metal (e.g., Cu, Al, Ag, Au, Fe, Ni, Pt, Sn, Pb, Zn, Si) and carbon (e.g., graphite) at a temperature sufficient to maintain the mixture in the molten state in a reactor vessel, while passing an electric current through the molten mixture via at least two spaced electrodes submerged or partially submerged in the molten metal. Each of the electrodes has an electrical conductivity that is at least about 50 percent of the electrical conductivity of the molten mixture at the temperature of the molten mixture. Preferably, the conductivity of the electrodes is equal to or greater than the conductivity of the molten mixture.

Please refer to Topic 9 (AMO) for other opportunities related to Advanced Manufacturing technologies.

Patent Status:

- U.S. Patent No. 10,662,509 B2, "Metal-carbon composition and composite manufacturing method" Issued May 26, 2020.

- U.S. Patent Application No. US 2019/0381563 A1 "Method for making metal-nanostructured carbon composite

- U.S. Patent Application No. US 2020/0176573 A1 "Electrodes for making nanocarbon - infused metals and alloys"

Questions – Contact: John Ahn, jahn@anl.gov, Argonne National Laboratory and Tina Kaarsberg, Advanced Manufacturing Office, Tina.Kaarsberg@ee.doe.gov

b. Electricity Delivery System Applications (CABLE)

This subtopic solicits innovative research and development (R&D) proposals that can enable breakthrough applications to better secure the national grid and make efficiency and affordability improvements to electricity delivery system (EDS) infrastructure. This subtopic is being jointly supported by the Office of Electricity and the EERE Advanced Manufacturing Office.

The U.S. electricity delivery system is currently undergoing a transformation as the importance of grid reliability and resilience is realized in the face of evolving threats (including cyber-attacks and extreme weather), and state and local policies increase penetration of renewable energy and distributed energy resources (DERs). To ensure reliable and secure electricity delivery in the future grid through these changes, technological advancements in transmission & distribution (T&D) infrastructure must be made [1]. Specifically, improvements are required in T&D infrastructure, and at their most fundamental, the material that transports power: conductors, and their application in transmission cables.

This subtopic seeks proposals to integrate affordable high-performance conductors into transmission and distribution applications to provide numerous benefits to EDS and other power-carrying applications (including overhead, underground and underwater cables). Lines or cables with significantly improved conductivity yield transmission benefits including minimized losses, increased strength, reduced sag and improved carrying capacity, all of which improve performance and operations. Improved-performance conductors promise immense benefits to all system stakeholders [2]. To the grid operator, the benefits from installing advanced lines and cables include increased grid reliability and resilience. To the customer, use of such lines and cables results in significant cost savings.

The primary goal of this subtopic is to design a proof-of-concept conductor for medium- to long- distance transmission lines and cables. In performing this design research, both desired properties and design specifications must be considered.

Desired properties of conductors for EDS applications include [3]:

- Low resistance to minimize electricity loss.
- Improved mechanical strength for maximized reliability.
  - Improved tensile strength.
  - Improved mechanical bend fatigue performance.
- Improved thermal conductivity.
- Improved melting points to maintain high operational strength.
- High ductility for mechanical flexibility.
- Earth-abundant content for minimized cost.
- Recyclable and safe material end-of-life.

Maximizing one or several of these properties in the proposed conductor design is a priority of this subtopic. In addition, proposals to this subtopic must explain how they support OE's goals for innovative transmission reliability, resilient distribution systems, energy storage, and advanced grid components. Proposals are encouraged to draw upon AMO-sponsored innovations in advanced material manufacturing, particularly for high performance conductors. Advanced manufacturing approaches such as additive manufacturing and roll-to-roll are encouraged where appropriate.

Use of a breakthrough in one property must be complemented by maintaining the other properties above minimum accepted values, with minimum standards described in each area of interest below. This is to balance a "breakthrough, leapfrog" improvement with minimums that support applicability and future commercialization. Expected improvements in metrics and how the improvements compare to the current state of the art must be clearly stated in proposals in response to this subtopic. Designs should maximize economic performance, demonstrate financial viability, and establish a credible pathway to commercialization.

A related consideration is meeting external design parameters. Rural utilities and co-operatives generally rely on USDA Rural Utility Service (RUS) specifications (and minimum accepted values) for designing and implementing electric infrastructure in their jurisdiction. Designing conductors that may be used in these areas removes one barrier from future commercialization potential. Properties of interest in these standards are more practical for the electric delivery application and include:

- Operating voltage
- Line current
- Conductor Size
- Max operating temperature
- Line voltage drop
- Power losses

The specific standards may be found at: https://www.rd.usda.gov/files/UEP_Bulletin_1724E-200.pdf [4]. The linked standards detail aboveground cables specifically, but RUS also publishes standards for other applications, including underground cables. Following federal standards in designing these conductors may benefit future commercialization opportunities and will make the project more appealing to a wider market. While it is not strictly required to meet any specific set of RUS standards, or every single standard in this research, keeping them in mind while designing an advanced conductor proof-of-concept will be favorably viewed by reviewers.

Areas of interest for this topic include:

1. **Aluminum-Based Conductors**: Aluminum is primarily used for overhead transmission lines, as it provides high-conductivity and light-weight benefits for low cost. The most common aluminum-based conductors are aluminum conductor steel reinforced (ACSR), but other on-the-market options include ACCC, ACCR, and ACSS. As a material, aluminum has potential for overhead lines, and advanced manufacturing methods may yield unique advancements for aluminum-based conductors [5]. Table 1 describes desired minimum values for several properties of the proof-of-concept aluminum-based conductor. Due to the variable nature of properties of differently sized conductors, precise values may change depending on size and ampacity chosen of the conductor design. As stated earlier, these thresholds are approximate guidelines for property thresholds to maximize commercialization potential in the future; it is expected that the design meets CABLE goals with an affordable, breakthrough, and leapfrog design.

Property	Desired Threshold	Notes
Electrical conductivity	> 62% IACS	
Mechanical strength	Comparable to or stronger than that of on-the-market ACSR	Precise value may change depending on line rating
Resistance	< 0.2 Ω/1000ft	DC at 20°C

Ductility	Comparable to or stronger than that of on-the-market ACSR	Precise value may change depending on line rating
Cost	Should not exceed $2/foot finished product	May be substantially lower depending on line rating and manufacturing methods

2. **Copper-Based Conductors**: Copper-based conductors benefit from high conductivity and high strength but suffer from higher weight and costs. For medium- to long- distance transmission, these properties may make copper apt for underground or underwater applications, because the higher conductivity and strength increase reliability and efficiency. Aluminum-based conductors are by far the most common conductors for transmission applications, and thus there are fewer preferred requirements for a copper-based conductor. The proposed design should achieve over 100% IACS and must display viable application for undersea or underground cabling. Of utmost importance are minimizing cost while maximizing strength and conductivity. Discussing demonstrated viability for transmission application that may lead to future commercialization will help in the proposal.

3. **Other EDS Applications**: Not limited to strictly aluminum-based or copper-based conductors, there are other advanced technologies that support the specific goals of CABLE while bringing benefit to EDS. Proposals will be considered in the following areas. Adherence to standards and demonstrated grid-scale viability is essential to maintaining a strong application.

- Aluminum/ Copper composite materials
- Other conductor materials or cable designs that align with CABLE goals
- Grid-viable projects that support advanced materials integration into transmission infrastructure. This may include:
- Grid resilience and reliability innovations
- Advanced insulating materials for high-voltage application
- Conductor coatings for harsh conditions

This subtopic supports the Grid Modernization crosscut, emphasizing advancements for future grid architecture and technologies.

Questions – Contact: Benjamin Shrager, Office of Electricity, Benjamin.shrager@hq.doe.gov

c. Non-metallic Heat Exchangers (CABLE)

This subtopic solicits proposals for next-generation non-metallic heat exchanger systems to improve the energy efficiency of heat pumps and air conditioners over a broad range of operating conditions for building and industrial applications that leverage CABLE non-metallic materials with enhanced thermal conductivity.

Current state-of-the art, air-to-refrigerant heat exchangers typically use copper-tube, aluminum-fin construction, with internal enhancement in the tubes and lances or louvers in the fins to promote heat transfer. Metal derived heat exchanger designs are today's state-of-the art (SOA) heat exchangers, like microchannel heat exchangers (MCHX).
Prior R&D investment by DOE have looked at, high performance compact heat exchanger, low charge heat exchanger designs and rotating designs. The development of polymer or non-metal heat exchange designs are ideal due to their light weight, manufacturing potential, wide range of geometric design possibilities,

corrosion resistance, and potential to be low cost. Polymer heat exchangers have not taken off as a practicable solution due to their relatively low thermal conductivity.

Considering the potential advantages non-metallic enhanced conductivity materials afford, this subtopic seeks new designs for heat exchangers suitable for condensers or evaporators in air conditioners or heating-only heat pumps, as well as heat exchangers suitable for both condensing and evaporating for reversible heat pumps. All solutions must have the potential to enable the market acceptance at scale.

Given the wide range of technology suitable for this subtopic, specific application targets are not defined but proposed innovations must exceed the state-of-the-art performance significantly. Applications must demonstrate progress in Phase I and achievement in Phase II of the following performance and cost targets:

Non-metallic Heat Exchangers	
Requirements	Targets
Performance, heat transfer rate (UA)	> 500% compared to state-of-the-art designs
Physical size	> 50% reduction compared to state-of-the-art designs
Fan, blower, or pump parasitic energy consumption	> 30% reduction compared to state-of-the-art designs
Required cleaning intervals, or difficulty of cleaning, to maintain as-new performance	Little to no increase as compared to state-of-the-art designs
Susceptibility to damage or corrosion or performance degradation during manufacture, assembly, transportation, installation, or use	Little to no increase as compared to state-of-the-art designs for relevant applications
Defrost requirements (for applications such as outdoor air-to-refrigerant heat exchangers)	Little to no increase as compared to state-of-the-art designs
Material Cost	> 40% lower cost compared to Aluminum design, lowest-cost material/designs

Please refer to Topic 12 (BTO) for other opportunities related to Building technologies.

Questions – Contact: Robert Aasen, Building Technologies Office, Robert.Aasen@ee.doe.gov

d. Ice-storage and Other Thermal Storage-related Systems (CABLE)

This subtopic solicits proposals for high performance (efficient and cost-effective) ice-based thermal storage technologies that leverage CABLE enhanced thermal conductivity materials.

The water-ice phase change is attractive for thermal (cold) energy storage because of its large heat of fusion resulting in high energy density, low cost, near constant storage temperature (melt temperature) along with minimal environmental impact. Applications of ice storage include heating, ventilation, and air-conditioning (HVAC) and refrigeration technologies, including direct expansion and chilled water, load balancing, integrating renewable energy sources into the grid, etc.

During ice storage charging, a heat transfer fluid at a lower temperature is used to form ice, and during discharging, the process is reversed and ice melts into water and the heat transfer fluid is cooled down.

The challenge with ice storage is that ice is a relatively poor thermal conductor. Thus, as ice is formed it becomes kinetically prohibitive to form more ice, limiting the total amount of stored energy over a fixed period. Typically, extensive piping is used to increase the total energy stored. Moreover, this approach leads to increased overall footprint and cost of the storage systems often making them marginally- or non-economical.

This subtopic therefore will support proposals that look to overcome these issues associated with thermal energy storage through new materials and thermal control approaches. This subtopic is interested in both passive and active approaches such as novel materials, high conductivity reinforcements, tunable conductivity, and use of external stimuli to control thermal conductivity.

Key metrics for such technologies are shown in the table below. The first row highlights one of the most important areas needing improvement: the time it takes or the rate at which the storage systems are charged and discharged. Applications must demonstrate progress in Phase I and achievement in Phase II of the following performance and cost targets.

High Performance Ice Storage Systems	
Requirements	Targets
Performance (charging/discharging rate)	>200% over current state of the art systems
Energy storage density (kWh/m3)	>80
Round Trip Efficiency (%)	>90%
Footprint	>50% reduction from the current state of the art ice storage systems
Durability/Reliability/Life-time	Similar or better than current state -of-the-art ice storage systems
Energy Storage System Cost ($/kWh)	<25

Please refer to Topic 12 (BTO) for other opportunities related to Building technologies.

Questions – Contact: Robert Aasen, Building Technologies Office, Robert.Aasen@ee.doe.gov

e. Electric Systems—Generators and Motors (CABLE)

This subtopic solicits proposals for more affordable, efficient direct current (DC), single-phase and three-phase alternating current (AC) electric motors/generators that leverage innovations in CABLE materials. Generator/motor systems with integrated power conversion system innovations that improve overall system performance are also of interest.

In 2019, the U.S. used 37.1 quadrillion Btu (quads) of primary energy to generate electricity for the grid and consumed approximately 13.75 quads of site electricity in 2018 [1, 2]. Of this, nearly 98 percent of the electricity came from mechanical generators [3]. On the demand side, electric motors consumed more 50 percent of all electrical energy in the US and more than 85 percent of industrial electrical energy. [4] Both generators and motors rely on electrically conductive materials. Generators convert mechanical power into electrical power while motors convert electrical power into mechanical power. Improving the performance of motors and generators is critical to the U.S. energy system. Advances in CABLE materials provide significant opportunity to increase the power density of motor and generator technologies while reducing energy losses, increasing performance, and providing for better and/or lower complexity thermal management of these systems. Proposals are sought in the following two areas of interest:

- Electrical generator technologies have been used in hydropower for more than a century in power generation applications. Recent growth in the renewable energy sector has highlighted the need for more flexible, efficient, and reliable technologies—particularly in distributed applications where continued innovation is needed to lower costs. Conventional grid connected generators are heavy, have a large form factor, and distributed systems must survive in harsh or extreme conditions, and often in remote and difficult to access locations (offshore wind and marine energy for example). This results in higher transportation and installation, operations, and maintenance (IO&M) costs and the need for complex thermal management systems – estimates suggest that operations and maintenance (O&M) costs make up 20%-30% of the lifecycle costs for offshore wind [2]. Advanced materials hold promise to meaningfully lower the cost of energy to end users by lowering the cost of O&M and through improvements to efficiency and capital costs.

- Motor-driven components used in heating, ventilation, and air conditioning (HVAC) and refrigeration are the highest energy consumers in the buildings sectors. Most of the residential and commercial equipment types covered in the residential and commercial sectors are covered by DOE energy conservation standards and industry standards such as ASHRAE 90.1. These standards continue to push manufacturers to consider both more efficient motors and variable-speed technologies, among other product design improvements, to meet more stringent minimum efficiency requirements. However, research efforts and incentives outside of DOE regulation would enable further reductions in motor-driven system energy consumption in the residential and commercial sectors.

Innovations in CABLE materials have great potential to increase the performance (including power density and reliability) of both motor and generator systems. Proposals for research that improve technologies in both motors and generators are of particular interest. Examples of broad research efforts that could improve both motor and generator system performance while reducing lifecycle costs include:

- Advanced manufacturing including additively manufactured parts and components;
- Power conversion systems that use wide bandgap semiconductors in place of conventional semiconductor materials and incorporate CABLE materials;
- Generators with integrated speed changing mechanisms such as magnetic gears;
- Applications that simplify or eliminate the need for thermal management (for example active vs passive cooling, air vs water).

All proposals should demonstrate performance improvements that take full advantage of CABLE material improvements primarily:

- Increased electrical conductivity; and/or
- Increased thermal conductivity.

Secondary improvements that also should be considered in a proposed solution include, but are not limited to:

- Ampacity
- Magnetic permeability
- Other thermal performance (temperature coefficient of resistance)

All proposals must consider the reliability of proposed systems and environment in which they operate (humidity, corrosion).

Given the wide range of technology suitable for this subtopic, specific application targets are not defined but proposed innovations must exceed the state-of-the-art performance significantly. Efforts to reduce the cost of advanced motor and generator technologies are essential for commercialization. Applications must demonstrate progress in Phase I and achievement in Phase II of the following performance and cost targets:

High Performance Motor Targets	
Requirements	Targets
Efficiency and/or lower cost R&D focus	40% lower cost (same performance compared to state-of-the-art or Energy Star equipment)
Size and weight	No increase as compared to the most recent minimum energy efficiency standards
Susceptibility to damage or corrosion or performance degradation during manufacture, assembly, transportation, installation, or use	Little to no increase as compared to state-of-the-art designs for relevant applications
High Performance Generator Targets	
Requirements	Targets
Power density	5% increase in power density (as compared to current state-of-the-art)
Smaller form factor and/or lower weight	10% improvement for specific application (as compared to current state-of-the-art)
Thermal performance	Improved thermal tolerance and/or ability to manage externally
System reliability	Comparable or better as compared to state-of-the-art designs for relevant applications

This subtopic is seeking systems that achieve the highest combination of reductions of size, cost, form factor, thermal management, and largest improvements in performance.

Please refer to Topic 12 (BTO) for other opportunities related to Building technologies and Topic 17 (WPTO) for opportunities related to Water Power technologies.

Questions – Contact: Robert Aasen, Building Technologies Office, Robert.Aasen@ee.doe.gov, and Erik Mauer, Water Power Technologies Office, erik.mauer@ee.doe.gov.

f. Photovoltaics Module and System Electrical Connections (CABLE)

This subtopic solicits proposals for innovative technologies and approaches that improve the quality and performance of photovoltaic (PV) electrical connections at the cell, module, or system level while reducing their cost.

Metal conductors extract the charges that light generates in solar cells so they can flow to the rest of the solar array. These electrical conductors include the metal contacts on the solar cell, wiring, and connectors.

This subtopic seeks proposals for the application of new conductive materials and related technologies to advance the state of the art in two areas: cell and module metal contacts and interconnects and PV system electrical connections. Applicants must clearly indicate which of the two areas of interest being proposed.

1. Cell and module metal contacts and interconnects

There are strict requirements for making high-performance contacts and interconnects. Improvements in contacts are needed to increase the conductivity and durability while reducing their total cost of processing and raising the overall module performance. Applying the contact to the solar cell must: (1) not introduce too many recombination centers at the interface of the metal and the absorber material, because it would reduce the power output, (2) form an energetically favorable path at the interface for charges to move from the absorber material to the metal, and (3) be conductive enough to carry charges out of the cell without appreciable loss due to series resistance or shadowing. These technical requirements must all be met while maintaining low cost, reliability, durability over decades, and compatibility with the packaging materials and existing manufacturing processes. Meeting these requirements through the application of new materials has the potential to meet these requirements. A third of cell fabrication costs are attributed to metal contacts. Metal contact and interconnect costs are between 10% and 30% of the total module cost owing to the materials and processing costs.

Applications to this area should propose the development of new cell and module metallization materials and processes. Applicants are expected to include objectives and milestones targeting a recombination current density (Jo) of the metallization contact of less than 10 fA/cm2, contact shading < 3% of active area, a cell fill factor of greater than 80%, and improved durability under chemical, thermal, and mechanical stresses that a module will experience in the field. The total cost for the metal contact materials and manufacturing step should be less than half of current costs, and projects must show that final mini-module test structures have better energy yield than a comparable baseline that uses state-of-the-art technology.

2. PV system electrical connections

Innovations in wire management and cable attachment present an opportunity to extend system durability well beyond the traditional 25-30-year PV plant life. EERE's goal is to extend the operational life of PV systems to 50 years. Critical interfaces and conductors must be capable of maintaining low-resistance electrical pathways despite thermal cycling, moisture ingress, mechanical loading, and other environmental challenges. At the utility scale, designs that increase the mechanical robustness of cabling interfaces, such as the attachment point to a tracker or designs that increase the installation speed of a PV plant, may result in lower levelized cost of electricity (LCOE) through lower operation and maintenance (O&M) and capital expenditures (CapEx) costs.

Applications in this area must demonstrate improved durability under accelerated life testing commensurate with a 50-year system lifetime with equivalent or improved electrical conductivity. Novel solutions for integrated wire management, such as cabling embedded in module framing or racking, may improve resistance to animal and environmental damage, thus avoiding expensive repair and replacement costs over the life of the system. The goal of this subtopic is to double the durability of PV systems or residential cabling and cabling attachments while reducing both installation time and bill-of-materials cost by 10%. Applicants must demonstrate the improvement by relevant component-level testing, using state-of-the-art, commercially available products for comparison.

Please refer to Topic 16 (SETO) for other opportunities related to solar energy technologies other than module and system electrical connections.

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

g. Geothermal: Direct Use and Electricity Generation Applications (CABLE)

The Geothermal Technologies Office (GTO) collaborates with the geothermal community with the goal of increasing geothermal electricity generation and the use of geothermal heat pumps and district heating by 2050 [1]. This subtopic solicits innovative research and development projects using enhanced conductivity materials or technologies in subsurface reservoir/wellbore environments for geothermal direct use applications and/or at electricity-producing geothermal power plants in order to reduce the levelized cost of heat or electricity.

For both direct use and power plants, GTO is seeking applications using enhanced conductivity materials to improve the thermal conductivity and heat transferred from the subsurface environment to the surface. For electricity-producing geothermal power plants, proposed materials and technologies must be designed for use in harsh downhole environments with elevated temperatures of greater than 225°C. For direct use applications, temperatures are typically lower than for electricity-producing power plants, but many similar technical challenges exist. Applications may include, but are not limited to the following:

- Improved wellbore materials such as high-conductivity cement or grout;
- Working fluids that optimize the net energy capture; and/or
- Improving the thermal conductivity within the geothermal reservoir.

Applicants must include performance targets for the proposed technology that can be benchmarked to comparable state-of-the art applications. Innovation into surfaced-based improvements, superconductive materials, or other types of standard operational efficiency improvements will be deemed non-responsive.

Please refer to Topic 1213 (GTO) for other opportunities related to geothermal energy technologies other than subsurface applications of enhanced conductivity materials.

Questions – Contact: William Vandermeer, Geothermal Technologies Office, William.Vandermeer@ee.doe.gov

h. Enhanced Conductivity EV Charging Cables and Couplers (CABLE)

This subtopic is soliciting proposals for the application of CABLE materials for new designs for wires and charging couplers for use in the recharging of electric vehicles.

As more and more vehicles are electrified, the energy losses in the charging couplers used to recharge these vehicles will continue to grow especially as ever faster charging powers are considered [1]. Improvements in the conductive materials used in the wire and contacts in the SAE J1772 DC charging coupler and cable, that operate at up to 400A and 1000V, are sought to reduce these energy losses.

Proposed improved material and coupler designs must consider all requirements for electric vehicle couplers including thermal, electrical, and other safety standards (e.g., UL 2202, UL 2251, ISO 17409, IEC 62196, IEC 60309) while not decreasing cable flexibility or increasing the weight from existing cable designs. The lifetime energy loss reductions from the proposed material and coupler design should be calculated for the entire cable system from the Electrical Vehicle Supply Equipment to the inlet of the vehicle for the lifetime of the cable. The impact of corrosion, fatigue, thermal degradation, and other impacts to the material lifetime should also be considered.

Please refer to Topic 17 (VTO) for other opportunities related to vehicle technologies.

Questions – Contact: Lee Slezak, Vehicle Technologies Office, Lee.Slezak@ee.doe.gov

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1. For more information on the DOE offices that comprise CABLE see the following websites: Office of Electricity (OE) (https://www.energy.gov/oe/office-electricity); and those for seven Offices within DOE's Office of Efficiency and Renewable Energy (EERE): Advanced Manufacturing Office (AMO) (http://energy.gov/eere/amo), Building Technologies Office (BTO) (http://energy.gov/eere/buildings), Solar Energy Technologies Office (https://www.energy.gov/eere/solar/solar-energy-technologies-office), the Geothermal Technologies Office (GTO) (https://www.energy.gov/eere/geothermal), the Vehicle Technologies Office (VTO) (https://www.energy.gov/eere/vehicles/vehicle-technologies-office); the Wind Energy Technologies Office Wind Energy Technologies Office (WETO) (https://energy.gov/eere/wind) and the Water Power Technologies Office (WPTO) (http://energy.gov/eere/water/water-power-program).

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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.

21. 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:

Return to Table of Contents

A. Real-time Sampling & Analysis of Tank Waste with Remote or On-pipe Monitoring
B. Non-Intrusive Mercury Detection and Measurement
C. Other

a. Real-time Sampling & Analysis of Tank Waste with Remote or On-pipe Monitoring

Introduction: The chemical, radiological, and physical properties of nuclear and hazardous chemical tank waste need to be characterized to meet regulatory requirements and to provide information needed to support decisions and actions related to tank corrosion control (safety basis), industrial hygiene (e.g., worker safety/vapors), retrieval planning (technology selection), waste compatibility assessments for feed staging, waste treatment plant waste acceptance, and tank closure.

Challenge: The current approach to obtaining chemical, radiological, and physical properties of tank waste includes obtaining physical grab/core samples and having them analyzed by an analytical laboratory. The sampling tool that is selected to obtain physical samples typically includes a collection of available sampler technology that includes finger-trap samplers, clamshell samplers, drag samplers, auger samplers, core samplers, etc.

Data quality objectives (DQOs) for regulator-driven tank waste characterization are challenging to meet with physical sampling because:

- physical samples are often not representative of the tank volume that was sampled;
- a long backlog in sample collection and laboratory analysis can exist that slows turn-around times; and
- the cost to open a tank and perform sample collection and transport can be very high.

Need: Innovative sample analysis instrumentation is needed that can be deployed in waste tanks or in/on waste transfer slurry lines to perform in-situ/real-time analysis of Hanford waste. For example, instrumentation that can:

- perform density, viscosity and rheology measurements in pipes;
- perform particle size and concentration measurements in pipes;
- detect and quantify interstitial liquid levels in tanks;
- detect and quantify halides such as fluoride, chloride and iodine in tanks/pipes;
- detect and quantify total organic carbon in tanks/pipes; and
- detect and quantify arsenic, beryllium, cadmium, mercury, copper lead, chromium, cyanide, lead, mercury, nickel, selenium, silver, vanadium, zinc and other constituents.

Public Benefit: Adding real-time, in-situ sampling and analysis of hazardous waste in tanks and pipes with remote on-pipe or in-tank monitoring instrumentation will decrease worker exposure to tank waste hazards, such as harmful vapors, by decreasing the number of physical samples that must be taken collected from waste tanks/pipes, transported to an analytical laboratory, and handled during sample analysis. Real-time, in-situ sampling and analysis within tank farms is also expected to support more efficient tank farm and waste treatment/processing facility operations by reducing analysis time from weeks/months to seconds/minutes. More efficient operations will lead to closure of the ageing waste tank (and pipe) infrastructure as early as possible, which is in the best interest of the environment's and public's health and safety.

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov or Grover Chamberlain, grover.chamberlain@em.doe.gov

b. Non-Intrusive Mercury Detection and Measurement

Elemental mercury was extensively used at the Y-12 National Security Complex during the Cold War effort. Losses of significant amounts of mercury to building piping, equipment, and actual building structures (walls and floors – steel, concrete, drywall, Transit [asbestos boards and piping], clay tiles, etc.) occurred. Four former-use large industrial production facilities and their ancillary facilities are contaminated or may be contaminated with elemental and other mercury species to differing concentrations. These facilities are up to four floors in height, with footprints of several hundred thousand square feet each, and miles of piping both inside and outside the facilities, some with holdup and/or decaying conditions present.

This subtopic is focused on identifying technologies that can be used to non-intrusively detect elemental mercury in building materials, piping, equipment, and waste containers that will facilitate its segregation and removal. The technologies should be capable of detecting mercury in structures, piping, and equipment constructed of various materials/metals of varying thicknesses in the presence of solid residue materials. Detection equipment must be portable and capable of measuring in all orientations. Real-time analysis and display are preferable, with quantification of sufficient accuracy for use in meeting waste acceptance criteria based on meeting land disposal restrictions for mercury. Mapping of results should be addressed as well.

Questions – Contact: Latrincy Bates, Latrincy.Bates@em.doe.gov or Grover Chamberlain, grover.chamberlain@em.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: Latrincy Bates, Latrincy.Bates@em.doe.gov or Grover Chamberlain, grover.chamberlain@em.doe.gov

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Return to Table of Contents

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.

22. CARBON STORAGE R&D

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 Carbon Storage Program is developing technologies for commercial readiness beginning in 2025 that promote safe, secure, efficient, and affordable CO2 injection and containment in storage complexes in diverse geologic settings. Regarding pre-existing wells and boreholes, characterization of wellbore integrity or borehole conditions is an important task in making the decision to move forward with a large-scale carbon storage project. In addition, knowing the location of all wells in the area of review is critically important in setting up monitoring at a carbon storage site. Deep legacy wellbores represent a potential leakage pathway for CO2 stored underground and may not be identified until found through detection of abnormal fluid movement during injection operations. Old wellbores can be difficult to locate because of incomplete or missing records, location in overgrown or wooded areas, or wellbore damage or collapse. Wellbores without metal surface casing cannot be located using electromagnetic sensors. Reported locations in old well records can easily be incorrect by hundreds of feet, especially for very old wells that were not formally surveyed. There are also legacy wells for which no records exist.

Once detected, technologies, correlations and workflows are needed to assess the condition of the entire wellbore or bore hole. This may include quantifying uncertainties about wellbore conditions that would relate to long-term containment of CO2 in the storage complex. Characterization of legacy wellbores is more challenging when re-entry is complicated by deteriorated conditions of the wellbore. Existing technologies can perform a reasonable job evaluating the casing-to-cement interface in a new well. However, older wells, especially those that have been through many pressure cycles, have usually developed annular cracks between the casing and cement that makes it much more difficult to evaluate the hydraulic integrity. Furthermore, cracks may develop between the cement and borehole wall, and little is known about how to evaluate the integrity of the cement-to-rock interface.

Grant applications are sought for the following subtopic:

Return to Table of Contents

a. Technologies for Detection and Characterization of Legacy Wellbores: Carbon Storage

Grant applications are sought that develop technologies to (1) detect legacy wellbores that lack a steel surface casing or (2) assess the integrity of legacy wells in which conventional logging tools cannot provide the needed information. New, innovative methods, tools or sensors are sought that can be used remotely, for example from an aerial platform, to locate within an area of review the legacy wells that would not be readily detected by visual/photographic inspection, lidar imagery analysis, or aero-magnetic survey signatures. New sensors, tools, methods or combinations thereof, that can characterize the hydraulic integrity of a wellbore out to the formation face at high resolution or through/around a plug, no matter the age or condition of the well, are also sought. These sensors, tools, and methods should help the user to assess the integrity of the wellbore and quantify integrity uncertainties. Uncertainties can include channels in the cement (or uneven cement placement), cement contamination, cement coverage less than documented or required, poor cement bonding to casing or formation, corrosion in casing, and plug quality. 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.

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

b. 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

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1. Carey, B. "Well Integrity and Carbon Storage." *Los Alamos National Laboratory*. May 12, 2016, California Air Resources Board Web Seminar, 2016, https://ww3.arb.ca.gov/cc/ccs/meetings/los_alamos_presentation_5-12-16.pdf

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23. SUPERCRITICAL CARBON DIOXIDE (SCO2)

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

Power cycles based on a supercritical carbon dioxide (sCO2) working fluid have the potential for higher thermal efficiencies and a lower capital cost when compared to state-of-the-art steam-based power cycles. These potential benefits, combined with the compounding performance benefits from a more efficient cycle on balance of plant requirements, fuel use, emissions, water use and cost-of-electricity (COE), are creating broad interest in sCO2 power cycles. The indirect sCO2 recompression Brayton cycle has the advantage of using a wide range of thermal heat sources (e.g., nuclear, concentrated solar, fossil, waste heat). This results in the power plant design being dependent on the temperature of this thermal heat source with the overall efficiency usually increasing with temperature. System analysis studies by many research organizations including NETL have projected efficiency improvements of 2 – 6 percentage points when compared with Rankine cycles operating at similar process conditions.

Grant applications are sought in the following topics:

a. Supercritical Carbon Dioxide Resistant Coatings for Turbomachinery

Thermal barrier coatings (TBC) and anti-friction coatings are known to provide benefits for turbomachinery in power cycles, including higher use temperature, greater erosion resistance, toughness, and improved sintering resistance, increased wear-resistance and component lifetime. However, the use of TBCs and anti-friction coatings is not as well-investigated for sCO2-based power cycles, where the working fluid is supercritical CO2. Applications are being sought for the research and development of optimum thermal barrier and anti-friction coatings for large-scale sCO2 Recompression closed Brayton cycle (RCBC) turbomachinery applications. Applicants should identify and investigate TBC and/or anti-friction coatings that are sCO2-resistant with appropriate application methods for large-scale turbomachinery at conditions relevant to the sCO2 RCBC. The high density of the CO2 and small turbine pressure drop creates compact turbomachinery with unique temperature gradients. The proposed coating must be tolerant against delamination, erosion (surface requirement) resistant to corrosive gas, support thermal gradients / cycling and offer a thermal barrier. Testing should be designed to identify optimum coatings. The applicant team should have access to an sCO2 testing facility. Applicants should clearly describe the coating materials, technology, and expected benefits to turbomachinery for indirect sCO2 power cycle applications. Applications should also include a description of preliminary results of the proposed coatings showing promising performance under sCO2 conditions. Collaboration with an OEM is encouraged. The proposed materials or coating techniques are preferred to be at a later-stage in the research and development process so they will be ready for commercial potential in Phase II.

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

b. Advanced Coolers for Supercritical Carbon Dioxide Base Power Cycles

A pathway to achieving higher sCO2 power cycle efficiencies can be enabled by operating under condensing sCO2 cycle conditions. The pressure drop through the cooler plays a large factor in the sCO2 cycle efficiency. These coolers are typically modular and to meet the desired heat duty multiple modules are used in a system, typically with heat duties ranging from 1 – 3 MWth per module.

Applications are being sought for the research and development of such advanced coolers to directly cool and condense CO2 while minimizing the pressure drop and associated fan power. Applicants should focus on the conceptual design of the cooler, integration with the sCO2 power cycle, and modeling performance. Controllability of the cooler to rapidly and accurately achieve the desired outlet temperature must be considered, due to the proximity of this operating point to the CO2 critical point and its resulting implications for downstream compressor performance. Cooler module designs resulting in a reduction in metal mass should be considered to enhance controllability and response transients. Applications may also include basic experimental work (cooler tubing geometries, heat transfer) to validate the concept. The applicant must clearly describe how the cooler technology will be integrated into the sCO2 power cycle to improve the cycle performance. Applicants must also describe how the proposed cooler technology can reduce cost compared to commercial technologies. The phase I effort should include development of a plan for building and testing a cooler prototype.

Questions – Contact: Drew O'Connell, Andrew.Oconnell@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: Mark Freeman, Mark.Freeman@netl.doe.gov

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24. RARE EARTH ELEMENTS AND CRITICAL MINERALS FROM COAL-BASED RESOURCES

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

America's critical materials and manufacturing supply chains for production of commodity and national defense products no longer reside on our domestic shores but are controlled predominantly by offshore markets. When viewed in its entirety, the rare earth element (REE) and critical minerals (CM) supply chains consist of mining, separation, refining, alloying, and ultimately manufacturing devices and components. A major issue with respect to REE development in the U.S. is the lack of refining, alloying, and fabricating capacity that could process any domestic rare earth production [1].

Efforts conducted under DOE-NETL's Feasibility of Recovering Rare Earth Elements (REE) program between 2014 and 2020, successfully demonstrated the very first step for the utilization of coal and coal-based resources to produce rare earth elements needed for our commodity and defense industries. This achievement was marked by demonstrating the technical feasibility and processing capability to extract and separate REE from domestic coal-based resources (i.e., run-of-mine coal, coal refuse (mineral matter that is removed from coal prior to shipment), clay/sandstone over/under-burden materials, ash (coal combustion residuals), and aqueous effluents such as acid mine drainage (AMD), and associated solids and precipitates resulting from AMD treatment), and recovery of these materials as mixed rare earth oxides or salts (MREO/MRES) at levels of 96-98% purity (960,000-980,000ppm) in three, first-of-a-kind, domestic, small pilot-scale facilities.

Currently, under DOE/NETL's RD&D program, state-of-the-art, conventional separation process concepts are being assessed for near-future production of 1-3 tonnes/day of high-purity MREO in engineering prototype facilities. Conversion of the MREO/MRES into individually separated, high purity REO/RES, and subsequently conversion to metals (MREM/MRES) will be essential for alloying and/or incorporation of these materials into intermediate products (i.e., magnets; etc.) or into manufactured end-products (i.e., wind turbines; fuel cells; etc).

Building on the accomplishments achieved in DOE-NETL's Feasibility of Recovering Rare Earth Elements program, efforts in 2019 were additionally directed to co-production of critical minerals (CM), as cobalt (Co), manganese (Mn), lithium (Li), and potentially aluminum (Al), zinc (Zn), germanium (Ge), and gallium (Ga) from domestic, coal-based, REE-containing feedstock materials. This expansion aligned DOE-NETL's effort to support Executive Order 13817 [2], which lead to changing the name of DOE-NETL's program in 2020 to Critical Minerals Sustainability.

Grant applications are sought in the following subtopics:

a. Advanced Technology Development for Production of Individually Separated, High Purity, (ISHP) Rare Earth Oxides/Rare Earth Salts (REO/RES)

Commercial sources of rare earth elements include bastnaesite (La, Ce)FCO3, monazite, (Ce, La, Y, Th)PO4, and xenotime, YPO4. Processing of these materials to extract and recover REE typically begins with physical beneficiation (mineral processing as crushing, grinding, density separation, magnetic separation, etc.), and is typically followed by chemical separation (i.e., hydrometallurgy: the technique or process of extracting metals at ordinary temperatures by leaching ores with liquid solvents), leading to the production of a mixed rare earth concentrate. Separation of the individual rare earths from each other was considered to be difficult, due to similar physical and chemical properties of the elements. Ion-exchange and solvent extraction techniques were developed in order to produce high purity single rare earth solutions or compounds. Alternate methods to concentrate, recover and separate rare earths include precipitation and coprecipitation, electrochemical and membrane processes, adsorption as well as oxidation and reduction processes.

Solvent extraction is generally accepted as the primary commercial technology for separating rare earths. Rare earth solvent extraction processes are generally classified as primary separations, which focus on separating rare earth elements from other elements, and secondary separations, which produce single or mixed (typically 2 or 3) rare earth products from mixed rare earth streams that are produced by primary separations. Commercially, D2EHPA, HEHEHP, Versatic 10, TBP, and Aliquat 336 have been widely used in rare earth solvent extraction processes. Up to hundreds of stages of mixers and settlers may need to be assembled in order to achieve the necessary extent of separation and product purity [1,2].

Applicants shall focus their proposals on:

- Providing a summary review of (1) the literature with respect to the state-of-the-art techniques and (2) utilization of these techniques for the separation of mixed rare earth oxides (MREO) and rare earth salts (MRES) into individually separated, high purity (ISHP) materials. These techniques shall include, but not be limited to solvent extraction, ion chromatography, electrowinning, sublimation/condensation, etc.
- Concept development for advanced processes/methodologies that address production of individually separated, high purity (i.e., ~90-99.99%) (ISHP), rare earth oxides (REO) and/or rare earth salts (RES) at a cost that is ~20% lower than the cost of producing these materials using currently available conventional separations technologies as solvent extraction, or alternate proven or commercially utilized separation techniques. Provide a detailed description of proposed advanced ISHP, reduced cost, separation processes.
- Laboratory-scale proof-of-concept testing demonstrating
    - Separation of mixed light rare earth oxides/rare earth salts (MLREO/MLRES) from heavy rare earth oxides/rare earth salts (HREO/HRES)
    - Separation of the MLREO/MLRES into ISHP LREO/LRES
    - Separation of the MHREO/MHRES into ISHP HREO/HRES at a cost that is ~20% lower than that of conventional, commercially used, technologies.
- Conduct of a preliminary techno-economic assessment (TEA) to address/validate the ~20% reduction of processing costs for each advanced separation concept.
- Preliminary systems design for process scale-up for production 100-1000gm of ISHP REO/RES materials.
- Final Report addressing each of the bulleted items identified above.

Questions – Contact: Mark Render, mark.render@netl.doe.gov

b. Advanced Technology Development for Production of Rare Earth Metals

Approximately 40% of mined rare earth production is reduced to metals and alloys, including most of neodymium (Nd), samarium (Sm), and dysprosium (Dy), for applications such as neodymium metal for Nd-Fe-B permanent magnets, samarium metal for Sm-Co permanent magnets, lanthanum (La), cerium (Ce), praseodymium (Pr), and neodymium (Nd) for rechargeable battery electrodes [1].

"A major issue for REE development in the United States is the lack of refining, alloying, and fabricating capacity that could process any future rare earth production [2]." The objective of the Advanced Technology Development for Production of Rare Earth Metals effort is to expand technology development beyond producing salable rare earth oxides (REO) from coal-based resources, ultimately producing rare earth metals (REMs) for use in intermediate and/or end product commercial and/or defense equipment through development of advanced metallization processing concepts.

Current technology utilizes metallothermic high temperature reduction with very strong reductants such as lanthanum and calcium, or high temperature fused salt electrowinning whereby rare earths are dissolved in molten halide salt solutions and reduced by an external direct current power source. Details on the history and the many techniques for the reduction of rare earths compounds to metals can be found in Gupta and Krishnamurthy 2005 [3].

Applicants shall focus their proposals on:

- Development of advanced, novel, rare earth oxides/salts (REO/RES) to rare earth metals (REM) reduction techniques.
- Production and analytic characterization of small quantities of individually separated, high purity (ISHP) REM resulting from advanced, novel, REO-REM reduction processes.
- Conduct of preliminary techno-economic assessment (TEA).
- Preliminary design for process scale-up.
- Final Report addressing each of the bulleted items identified above.

Questions – Contact: Mark Render, mark.render@netl.doe.gov

c. Production of Critical Minerals from Coal-Based Resources

In the U.S. DOE 2011 Critical Materials Strategy report [1], sixteen elements were assessed for criticality in wind turbines, EVs, PV cells and fluorescent lighting. The criticality assessment was framed in two dimensions: importance to clean energy and supply risk. Five rare earth elements (REE)—dysprosium, terbium, europium, neodymium and yttrium—were found to be critical in the short term (2011–2015). These five REE are used in magnets for wind turbines and electric vehicles or phosphors in energy-efficient lighting. Other elements—cerium, indium, lanthanum and tellurium—were found to be near-critical. Between the short term and the medium term (2015–2025), the importance to clean energy and supply risk shift for some materials.

U.S. Executive Order 13817 [2], which was issued on December 20, 2017, focused on the reduction of our Nation's vulnerability to disruption in the supply of critical minerals. In Executive Order 13817, a critical mineral is a mineral identified to be a non-fuel mineral or mineral material essential to the economic and national security of the United States, the supply chain of which is vulnerable to disruption, and that serves an essential function in the manufacturing of a product, the absence of which would have significant consequences for the economy or national security. Critical minerals were identified to include 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 [3].

As DOE-NETL has demonstrated the technical feasibility of recovering rare earth elements from coal-based resources, efforts are being extended to address the feasibility of recovering critical minerals from run-of-mine coal, coal refuse (mineral matter that is removed from coal prior to shipment), clay/sandstone over/under-burden materials, ash (coal combustion residuals), and aqueous effluents such as acid mine drainage (AMD), and associated solids and precipitates resulting from AMD treatment.

Applicants shall focus their proposals on:

- Providing a summary review of the open literature that addresses the industrial processing of all thirty-seven (37) critical minerals from conventional resources. Processing methodologies as well as the annual production quantities and current utilization for all thirty-seven (37) critical minerals shall be described.

- Production of critical minerals from coal-based (unconventional) resources shall be addressed. This shall include identifying:
  - o Critical mineral concentrations in coal-based resources (highest ranked anthracite coal through low grade lignite; coal combustion ash; AMD; etc.)
  - o Concepts for extraction, separation and recovery of critical minerals based on:
    - Potential technology transfer utilizing conventional industrial processing for extraction, separation and recovery of critical minerals from coal-based resources
    - Prior state-of-the-art for extraction, separation and recovery of critical minerals from coal-based resources
    - Projected critical mineral phase(s) resulting from processing (i.e., metals, oxides, salts, etc.)
    - Development of conceptual process flow diagrams (PFD) for the extraction, separation and recovery of critical minerals from coal-based resources.
- Utilization of critical minerals for advanced alloy development or component production.
- Final Report addressing each of the bulleted items identified above.

Questions – Contact: Mark Render, mark.render@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 Render, mark.render@netl.doe.gov

References: Subtopic a:

1. Fang, X., Zhang, T.A., Dreisinger, D., Doyle, F. “A Critical Review on Solvent Extraction of Rare Earths from Aqueous Solutions.” *Minerals Engineering, Vo. 56*, February 2014, p.10-28, https://www.sciencedirect.com/science/article/pii/S0892687513003452

2. Kolodynska, D., Fila, D., Gajda, B., Gega, J., Hubicki, Z. “Rare Earth Elements—Separation Methods Yesterday and Today.” *Applications of Ion Exchange Materials in the Environment*, pp 161-185, February 2019, https://link.springer.com/chapter/10.1007/978-3-030-10430-6_8

References: Subtopic b:

1. Lucas, J., Lucas, P., Le Mercier, T., Rollat, A., and Davenport, W., “Rare Earths: Science, Technology, Production and Use.” Elsevier, 2014, https://arizona.pure.elsevier.com/en/publications/rare-earths-science-technology-production-and-use

2. Humphries, M. “Rare Earth Elements: The Global Supply Chain.” *Congressional Research Service* Washington, DC., 2013, https://fas.org/sgp/crs/natsec/R41347.pdf#:~:text=Rare%20Earth%20Elements%3A%20The%20Global%20Supply%20Chain%20Congressional,chemical%20group%20called%20lanthanides%2C%20plus%20yttrium%20and%20scandium

3. Gupta, C., and Krishnamurthy, N. “Extractive Metallurgy of Rare Earths.” *CRC,* Boca Raton, FL: 28-56, 2005, https://www.goodreads.com/book/show/88554.Extractive_Metallurgy_of_Rare_Earths

References: Subtopic c:

1. U.S. Department of Energy. "Critical Minerals Strategy." *Energy.gov*, December 2011, https://www.energy.gov/node/349057

2. Executive Order 13817. "A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals." December 20, 2017. *List of Critical Minerals posted in Federal Register/Vol. 83*, No. 97/Friday, May 18, 2018/Notices, https://www.federalregister.gov/documents/2017/12/26/2017-27899/a-federal-strategy-to-ensure-secure-and-reliable-supplies-of-critical-minerals

3. U.S. DOI, Press Release. "Interior Seeks Public Comment on Draft List of 35 Minerals Deemed Critical to U.S. National Security and the Economy." February 16, 2018, https://www.doi.gov/pressreleases/interior-seeks-public-comment-draft-list-35-minerals-deemed-critical-us-national

25. CARBON CAPTURE

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.
For almost two decades, DOE's Office of Fossil Energy (FE) has been developing technologies to remove CO2 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).

Grant applications are sought in the following subtopic:

a. Novel Cryogenic 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 CO2 capture with 95% purity and with a cost of electricity at least 30% lower than a supercritical PC with CO2 capture, or approximately $30 per tonne of CO2 captured.1,2 The technologies can include both materials and processes used for advanced carbon capture. Grant applications are sought for novel cryogenic processes or hybrid cryogenic approaches that synergistically complement the cryogenic process with other separation techniques or materials (membranes, solvents or sorbents) to improve performance and lower the cost of CO2 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. Applications must show that the proposed cryogenic 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: Krista Hill, krista.hill@netl.doe.gov

b. Other

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

Return to Table of Contents

Questions – Contact: Krista Hill, krista.hill@netl.doe.gov

References:

1. National Energy Technology Laboratory. "Carbon Capture Program Fact Sheet." *U. S. Department of Energy*, p. 4, 2017, http://netl.doe.gov/sites/default/files/2017-11/Program-115.pdf
2. National Energy Technology Laboratory. "Carbon Capture Program." NETL Website, 2020, http://netl.doe.gov/coal/carbon-capture

26. UNCONVENTIONAL OIL & NATURAL GAS 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

Unconventional Oil and Gas (UOG) development has dramatically increased U.S. production of oil and natural gas over the past decade. The Energy Information Administration (EIA) estimates that crude oil production from unconventional (tight oil) reservoirs has increased from 16.5% of total U.S. production in 2008 (0.8 million barrels of oil per day (MMb/d)) to 56.5% of total U.S. production in 2018 (5.6 MMb/d). Over the same period, natural gas production from unconventional reservoirs has also increased from 16.8% of total U.S. production (3.4 trillion cubic feet (Tcf)) to 56.6% of total U.S. production (16.4 Tcf). Based on the EIA's 2018 Annual Energy Outlook, these trends are expected to continue through 2050 when UOG resources are projected to contribute 70.1% of total U.S. oil production (7.9 MMb/d) and 76.1% of total U.S. natural gas production (32.7 Tcf). Based on these projections, UOG production from existing and emerging plays will continue to play a vital role in U.S. energy security and dominance through 2050.

While the combination of extended-lateral horizontal drilling and high-volume hydraulic fracturing has led to the significant production increases discussed above, the full potential of U.S. UOG resources has yet to be realized. The recovery efficiency of UOG is difficult to bound, but the limited information available suggests that recovery factors are often despairingly low, perhaps 20% in gas-rich shale reservoirs and less than 10% in liquid-rich plays.

a. Advanced Shale Gas Recovery Technologies for Horizontal Well Completion Optimization

Advanced Shale Gas Recovery Technologies for Horizontal Well Completion Optimization Proposals are sought to develop and test technologies that will reduce the amount of or eliminate the water needed for hydraulic fracturing when completing natural gas wells or that will improve the apparent low (<30%) natural gas and liquids recovery efficiency currently associated with horizontal, hydraulically fractured wells producing from shale formations. Proposals should focus on addressing a number of important areas where cost effective improvements may be possible. The objective is to increase the efficiency of resource recovery on a per well basis or reduce the volume of fresh water required to produce a unit volume of natural gas.

For example, research could include quantitative assessments of the practical and economic limits and potential benefits (if any) of employing mixtures of natural gas (not LPG as is currently practiced) with conventional sand-laden fracturing fluids, as a novel fracturing fluid to partially replace water in the large volume, multiple stage hydraulic fracturing treatments representative of those being applied in shale gas and shale oil plays today.

Examples of analyses could include laboratory experiments and/or computer simulations that quantify the effect on relative permeability to gas in a producing wellbore when mixtures of conventional fracturing fluids and natural gas (versus fracturing liquids only) are employed as fracturing fluids under conditions representative of major shale gas plays. Research could characterize the potential volumes and rates of natural gas / conventional fracturing fluid mixtures required to achieve well productivity similar to that achieved when wells are fractured using conventional fracturing fluids alone.

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

b. Advanced Hydraulic Fracture Diagnostics for Unconventional Oil and Natural Gas Wells

This topic invites proposals for research that is focused on developing novel technologies for more accurately characterizing the orientation and dimensions of hydraulic fractures, in support of efforts to reduce the environmental risks and increase the efficiency of fracturing in unconventional oil and natural gas wells. Understanding the extent to which fractures may intersect with pathways to shallower water supplies is an important aspect of unconventional oil and gas resource development risk mitigation.

The current categories of diagnostic tools (Cipolla and Wright, 2000) include a variety of methods for near-wellbore fracture diagnostics (e.g., production and temperature logs, tracers, borehole imaging) as well as a variety of far-field techniques (e.g., microseismic fracture mapping), but none of these succeed in consistently providing a fully detailed and accurate description of the character of created fractures.

DOE has several projects currently underway that seek to expand the tools available for fracture diagnostics. These include a combination of highly sensitive borehole sensors coupled with proppant-sized acoustic emitters that can signal from within a created fracture, electromagnetic logging tools that can image the dimensions of a fracture filled with conductive proppant, enhanced logging methods and permanent downhole seismic sensors.

DOE is interested in building upon its existing research portfolio by developing new ways to reduce the cost and/or enhance the accuracy of existing or under-development technologies and methods for hydraulic fracture diagnostics, or by researching entirely new solutions.

Specific concepts could include innovative and breakthrough technologies for improved subsurface characterization, visualization, and diagnostics, including:

- Near-wellbore fracture diagnostic methods
- Far-field fracture diagnostic methods
- Intelligent proppant systems.

Questions – Contact: William Fincham, william.fincham@netl.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: William Fincham, william.fincham@netl.doe.gov

References: Subtopic a:

1. National Energy Technology Laboratory. "Using Natural Gas Liquids to Recover Unconventional Oil and Gas Resources." *U.S. DOE, NETL*, 2020, https://netl.doe.gov/node/9482

References: Subtopic b:
1. Cipolla, C.L. and Wright, C.A. "State-of-the-Art in Hydraulic Fracture Diagnostics." Presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition, Brisbane, Australia, 16–18 October. SPE-64434-MS, https://www.onepetro.org/conference-paper/SPE-64434-MS

2. National Energy Technology Laboratory. "Fracture Diagnostics Using Low Frequency Electromagnetic Induction and Electrically Conductive Proppants." U.S. DOE, NETL, 2017, http://www.netl.doe.gov/research/oil-and-gas/project-summaries/unconventional-resources/fe0024271-utaustin

3. National Energy Technology Laboratory. "Injection and Tracking of Micro-seismic emitters to Optimize Unconventional Oil and Gas (UOG) Development." U.S. DOE, NETL, 2020, http://www.netl.doe.gov/research/oil-and-gas/project-summaries/unconventional-resources/fe0024360-paulsson

4. National Energy Technology Laboratory. "Evaluation of Deep Subsurface Resistivity Imaging for Hydrofracture Monitoring." U.S. DOE, NETL, 2017, http://www.netl.doe.gov/research/oil-and-gas/project-summaries/natural-gas-resources/fe0013902-groundmetrics

27. NATURAL GAS TECHNOLOGIES: NATURAL GAS INFRASTRUCTURE

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 Oil and Gas Program's Natural Gas Infrastructure (NGI) R&D Technology Area supports research to advance the resiliency and flexibility of our Nation's natural gas transportation and storage infrastructure. These efforts include developing next-generation pipeline materials; improving the reliability of gathering, compression, and storage system components; creating sensor platforms capable of identifying and quantifying methane emissions, and advancing technologies for repairing pipeline damage without disruption of service.

This Area of Interest (AOI) seeks applications which propose research to develop tools, methods, and/or technologies that 1) improve hydrogen transport efficiency within existing natural gas infrastructure, 2) provide "real-time" monitoring capabilities for natural gas/hydrogen blends throughout transport, and 3) mitigate or eliminate hydrogen leakage from natural gas infrastructure. Applications under this AOI are required to address safety considerations related to the testing and implementation of technologies being proposed. In addition, applications under this AOI are encouraged to consider data needs with respect to data analytics and artificial intelligence concepts. As such, technologies developed under this AOI may address how the proposed technology fills critical data gaps needed for advanced data analytics.

Grant applications are sought in the following subtopics:

a. Hydrogen Transport
Novel technology approaches that in the future will enable the transport of hydrogen, in batches or in blends with natural gas, within the U.S. long-distance natural gas transmission system. Of interest are technologies that can significantly reduce the energy penalty associated with traditional compression methods when applied to low-molecular weight hydrogen gas. These approaches can include the

densification of hydrogen though physical or chemical means. Any proposed technology must mitigate the potential for hydrogen embrittlement, leakage of hydrogen through seals and connections, and other hydrogen safety risks.

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

b. Sensors for Hydrogen Monitoring

Advanced sensors for "real-time" monitoring of hydrogen concentration within a pipeline quality natural gas stream throughout transportation infrastructure for efficient end use. Such sensors can be stand-alone hydrogen concentration sensors or part of a more comprehensive set of sensing capabilities, and could include new designs or retro-fit modifications to existing sensor technologies. These sensors should be compatible with existing pipeline monitoring systems.

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

c. Hydrogen Leakage Detection and Mitigation

Technologies capable of detecting and mitigating hydrogen leakage throughout existing natural gas infrastructure. Such technologies could include new sensing tools, both fixed and mobile and for either remote or close-in detection. Mitigation technologies could include repair or replacement options, with the capability of retro-fit to existing equipment a high priority feature.

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

d. Other

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

Questions – Contact: William Fincham, william.fincham@netl.doe.gov

References: Subtopic a:

1. Office of Fossil Energy. "Hydrogen Strategy—Enabling A Low-Carbon Economy." *U.S Department of Energy*, 2020, https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf

References: Subtopic b:

1. Office of Fossil Energy. "Hydrogen Strategy—Enabling A Low-Carbon Economy." *U.S Department of Energy*, 2020, https://www.energy.gov/sites/prod/files/2020/07/f76/USDOE_FE_Hydrogen_Strategy_July2020.pdf

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1. Hoagland, B. "Hydrogen leak detection – low cost distributed gas sensors." *U.S. Department of Energy*, Element One, Inc, https://www.energy.gov/sites/prod/files/2014/03/f10/webinarslides_element_one_040312.pdf

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, technology relevant to magnetically confined plasma, and high energy density laboratory plasmas.

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

28. 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.

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

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.

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

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).

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

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

e. Other

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

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

References:

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

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29. 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: Guinevere Shaw, guinevere.shaw@science.doe.gov

b. Other

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

Questions – Contact: Guinevere Shaw, guinevere.shaw@science.doe.gov

References:

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

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30. HIGH ENERGY DENSITY LABORATORY PLASMAS

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.

Grant applications are sought in the following subtopics relevant to HEDLP and IFE:

a. 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 focusability. Specific areas of interest include but are not limited to: spatial and temporal contrast diagnostics, Measuring and controlling the timing of multiple laser and particle beams with femtosecond accuracy, wavelength and beam quality for lasers, brightness for lasers, pulse shaping, high damage threshold gratings, non-destructive characterization of optics for high-average-power (HAP) and high-peak-power (HPP) applications, improved polishing processes for nonlinear optics, and broadband coatings.

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

b. Ultra-fast Detectors for HED Applications

High speed detectors that record electromagnetic radiation over a wide frequency range, from the visible to the x-ray regions of the EM spectrum in both one dimensional and two-dimensional recording media will advance many HED applications. Specific areas of interest include but are not limited to: sub-ns Detector Systems for XFEL and synchrotron Applications, framing cameras for study of plasmas and shock-driven materials dynamics, and sub-ns framing cameras with high quantum efficiency for photon energies >20keV.

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

c. Other

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. "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, 2009, https://science.osti.gov/-/media/fes/fesac/pdf/2009/Fesac_hed_lp_report.pdf

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Return to Table of Contents

31. 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. U.S. Department of Energy. "Basic Research Needs Workshop for Microelectronics." *U.S. Department of Energy Office of Science*, 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. "Plasmas at the Interface of Chemistry and Biology." *Report on the Panel on Frontiers of Plasma Science*, chapter 5, 2016, https://science.osti.gov/-/media/fes/pdf/program-news/Frontiers_of_Plasma_Science_Final_Report.pdf?la=en&hash=85B22EBF1CF773FFC969622524D603D755881999

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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.

32. 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. Machine Learning, Diagnostics, Controls and Modeling

Machine learning (ML) promises significant enhancements for particle accelerator operations, including applications in diagnostics, controls, and modeling. However, it is essential that as these promising ML methods are experimentally demonstrated before being deployed at user facilities. The ability to generalize the training and deployment of ML algorithms to different operating configurations for the same beamline, or between facilities, remains a challenge. Proposals are sought to develop novel algorithms and associated software to support the training and deployment of ML tools at accelerator facilities. Developments, which facilitate domain transfer between facilities and diagnostic types, are highly encouraged. Successful proposals must include plans for experimental demonstration and validation.

Questions – Contact: John Boger, john.boger@science.doe.gov

b. Adaptive Online Machine Learning for Dynamic Beam Diagnostics

Particle accelerators are large complex systems composed of hundreds to thousands of interconnected electro-magnetic components including radio frequency (RF) resonant accelerating structures for beam acceleration and longitudinal focusing and various magnets for beam steering and transverse focusing. Charged particle beams are themselves complex objects living in a six-dimensional phase space. They undergo complex collective effects such as coherent synchrotron radiation and vary with time in unpredictable ways. Sources of variation include accelerator RF phase and amplitude jitter, and magnet current jitter, and time-varying laser intensities and photoemission at the beam source. As bunches become shorter and more intense, the effects of intra-bunch collective interactions such as space charge forces and bunch-to-bunch influences such as wakefields also increase. Short, intense bunches are extremely difficult to accurately image because their dimensions are beyond the resolution of existing diagnostics and they may be destructive to intercepting diagnostics.

Proposals are sought for the design and implementation of adaptive machine learning methods as applied to time-varying systems since they have the potential to aid in the diagnostics and control of high-intensity, ultrashort beams by interfacing online models with real time non-invasive beam data, and thereby provide a detailed virtual view of intense bunch dynamics. The goal is to enable beam prediction and control, and to develop new diagnostics in order to increase beam phase-space density by at least an order of magnitude than currently achievable.

(See References 1 through 6 for further information.)

Questions – Contact: John Boger, john.boger@science.doe.gov

c. Structure Wakefield Acceleration (SWFA)

Structure Wakefield Acceleration (SWFA) provides a viable path towards a future HEP linear collider. In order to continue progress along the 2016 SWFA Roadmap [7] improvements of both structures and bunch shaping systems are needed to realize beam-driven SWFA that operate with high-gradient (>few 100s MeV/m) and high rf-to-beam efficiency (>40%).

1. Proposals are sought for high-frequency structures (10 GHz - 1 THz) capable of high-gradient, low-loss, higher order mode damping and mutlipactor/field-emission mitigation. Structures for two-beam accelerators further require high-efficiency coupling schemes for short-pulse operation. Structures considered appropriate for this topic include, but are not limited to, metallic or dielectric, novel geometry (metamaterial, photonic bandgap, etc.), room temperature or cryogenic.

2. Proposals are also sought for bunch shaping systems for driving structures operating in a range from 10 GHz - 1 THz and capable of (i) shaping of high-charge bunches (>10 nC) with (<1 ps) resolution, (ii) generating multiple bunches with accurate time separation (<100 fs) with (iii) minimal charge losses (<10%). Such drive bunch shaping systems should target increasing the transformer ratio (>10) in collinear wakefield accelerator or increasing the utilization of the drive bunch energy (>80%) by reducing the beam-breakup instability. Witness bunch shaping systems should optimize beam-loading to achieve high rf-to-beam efficiency while being capable of operating in an environment with high-gradient, high net acceleration per structure (10s MeV energy gain) and beam quality preservation. Examples of bunch shaping systems include, but are not limited to, direct beam manipulation beamlines such as emittance exchange, round-to-flat transformers, deflecting cavities as well as 3D laser bunch shaping for photocathode guns.

Questions – Contact: John Boger, john.boger@science.doe.gov

d. Targetry: Radiation Resistant Strain/Vibration Instrumentation Development

Monitoring the health of a target component in situ requires strain instrumentation that can withstand the high radiation environment of a beam target. The accumulated dose of a future target component during its lifetime may exceed 10 Giga-Gray. Instrumentation that can function near to this limit is needed that can resolve strains as low as 100 nano-strain and as high as 10 milli-strain (non-concurrently). Sampling frequency is potentially as high as 4 MHz to capture the dynamic response of a high intensity beam pulse (1 to 10 microsec duration).

Proposal are sought for the development of radiation-hardened transducers for measuring transient strains in the range of 10-7 to 10-2 in the frequency range of 1 kHz to 4 MHz.

Questions – Contact: John Boger, john.boger@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: John Boger, john.boger@science.doe.gov

References:

1. Litos, M., Adli, E., An, W., Clarke, C., Clayton, C., Corde, S., Delahaye, J., England, R., Fisher, A., Frederico, J., et al., "High-efficiency acceleration of an electron beam in a plasma wakefield accelerator." *Nature 515*, 92, 2014, https://www.nature.com/articles/nature13882.

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3. Adli, E., Ahuja, A., Apsimon, O., Apsimon, R., Bachmann, A. M., Barrientos, D., Batsch, F., Bauche, J., Olsen, V.B., Bernardini, M., et al. "Acceleration of electrons in the plasma wakefield of a proton bunch." *Nature 561*, 363–367, 2018, https://www.nature.com/articles/s41586-018-0485-4

4. Joshi, C., Adli, E., An, W., Clayton, C.E., Corde, S., Gessner, S., Hogan, M.J., Litos, M., Lu, W., Marsh, K.A., et al. "Plasma wakefield acceleration experiments at FACET II." *Plasma Physics and Controlled Fusion 60*, 034001, 2018, https://iopscience.iop.org/article/10.1088/1361-6587/aaa2e3/meta

5. Scheinker, A., and Gessner, S. "Adaptive method for electron bunch profile prediction." *Physical Review Special*, Topics-Accelerators and Beams 18, 102801, 2015, https://doi.org/10.1103/PhysRevSTAB.18.102801

6. Scheinker, A., Edelen, A., Bohler, D., Emma, C., and Lutman, A. "Demonstration of model-independent control of the longitudinal phase space of electron beams in the linac-coherent light source with femtosecond resolution." *Physical review letters 121*, 044801, 2018, https://doi.org/10.1103/PhysRevLett.121.044801

7. "Advanced Accelerator Development Strategy Report: DOE Advanced Accelerator Concepts Research Roadmap Workshop." *U.S. DOE Office of Science*, Feb 03, 2016, https://www.osti.gov/biblio/1358081-advanced-accelerator-development-strategy-report-doe-advanced-accelerator-concepts-research-roadmap-workshop

33. 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.

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. Automation of SRF Cavity String Assembly

SRF cavities and other metallic components are assembled together in a cleanroom environment. At present the largest impact on the quality of the assembly is the human factor. In order to minimize this impact and also to decrease touch labor and cost, robot-assisted assembly technology is of great interest. Full digitalization of the assembly area, contactless measurement of the component positions, assisted positioning and alignment are some of the steps that could be implemented. The ultimate goal of the proposal submitted is to develop a contactless technology to reconstruct the pose of high-reflecting metallic components to enable robot assisted assembly of SRF components in a cleanroom environment.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

c. Advanced Conduction Cooling for SRF Systems

The implementation of cryocoolers to reach the operating temperature of both SRF and SC magnet devices is very appealing for compact accelerators as well as stand-alone experimental and medical applications. There are clear opportunities for technology advances that might improve such systems for these applications. Grant applications are sought for (1) coupling of the two stages of a cryocooler during the cooldown phase of the device to reduce the time required to reach operating temperature; (2) swapping of a cryocooler (for maintenance or failure) without breaking insulation vacuum and while keeping the system cold; (3) implementing 4 K and 50 K heat pipes to reduce gradients between cold head and device; (4) using hybrid graphene/copper thermal straps to reduce cooldown time.

Questions – Contact: Ken Marken, ken.marken@science.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.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

References:

1. Hartill, D. “Accelerating Discovery: A Strategic Plan for Accelerator R&D in the U.S.” *U.S. Department of Energy Office of Science*, April 2015, https://science.osti.gov/-/media/hep/hepap/pdf/Reports/Accelerator_RD_Subpanel_Report.pdf (see especially section 7).

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34. 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	M2<1.1	Strehl>0.95	M2<1.1	M2<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	<5o	N/A	<5o	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. High Energy and Broadband Components for Fiber Lasers and Arrays

Due to their high average power capability and high wall-plug efficiency, ultrafast fiber lasers are promising for driving high rep-rate laser-plasma accelerators, generating radiation from THz to gamma rays, and as important tools for material processing. Realizing this requires pulse energies and durations not now achievable from fiber lasers. Coherent combination of ultrafast fiber lasers, in spatial and temporal domains, potentially provides a path to pulse energies up to Joules, with high average powers and efficiencies well beyond the current generation of lasers. Pulse duration limitation of fiber lasers can be overcome using spectral combining of multi-band fiber lasers, which has the potential to achieve tens of femtosecond durations.

The practicality of aggregating a large number of fiber amplifiers motivates that each is implemented as a compact and robust module. However, current state-of-the-art specialty fibers with 50–100 micron core diameters, which produce the highest pulse energies in diffraction-limited beams, lack fiber-optic components which can be fusion-spliced into monolithically-integrated subsystems.
Spectral combining of ultrafast fiber lasers (Yb-doped) will need fiber components optimized at different bands within the Yb gain spectrum. However, most fiber components in the current market are optimized with a central wavelength only in the range of 1040-1065 nm, and a bandwidth up to ~30 nm.

Grant proposals are sought to demonstrate and develop fiber laser components for module integration (monolithic pump combiners, mode adapters, optical interconnects, residual-pump-power strippers, etc.), as well as complete integrated amplifier subsystems using 50–100 micron core specialty fibers with diffraction-limited output. These components and subsystems should sustain multi-mJ pulse energies and average powers in the 100 W – 1 kW range, when operating within the ~1 micron gain spectrum of Yb-doped fibers. In addition, proposals are sought to develop and demonstrate fiber components for spectral combination (WDMs, isolators, etc.), both single-mode and large-mode-area, with spectral boundaries extended to <1010 nm OR >1090 nm, and covering a broad band (>30-40 nm bandwidth)..

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. Advanced Quality Control Instruments and Services for Ultrafast Laser Optics

As scientific laser systems increase in repetition rate and peak power, the quality of optics and damage threshold of optics becomes increasingly critical. Laser Induced Damage Threshold (LIDT) and the overall performance of optics for high average power (HAP) and high peak power (HPP) applications varies greatly. Both linear optics (e.g., mirrors, gratings and transmissive optics), and nonlinear optics (e.g., gain materials, harmonic generation crystals) often perform quite differently, even from the same manufacturer.

Instrument for LIDT characterization. The surface preparation process is a critical factor in LIDT, and new and more accurate physical characterization methods are needed to improve fabrication processes and to qualify HAP optics. Techniques for revealing the causes of LIDT performance variations are of interest and include such techniques as fluorescence microscopy and photo-thermal heterodyne interferometry.

Instruments for Large-Aperture Optic Characterization. Equally important are high accuracy optical characterization capabilities suitable for large-format HAP and HPP optics that can range from cm-scale nonlinear crystals to meter-scale diffraction gratings. Properties such as the reflected/diffracted/transmitted wavefront error, dispersion uniformity, and doping concentration uniformity need to be accurately measured at sufficient spatial resolution (e.g. millimeter or better) over the full optical aperture. Stitching interferometry for linear optics, like mirrors & gratings, and deuteration mapping for DKDP crystals are of particular interest.

The successful proposal will propose (1) the development of an instrument, (2) measurement techniques, including data reduction and error estimation, (3) measurement validation and calibration techniques, and (4) complete a set of demonstration measurements on ultrafast HAP optics. An instrument capable of multiple simultaneous measurements (e.g., LIDT and doping concentration) would offer added efficiency and is especially interesting.

Final demonstration measurements must be made in the near-IR (0.7-2.5 micron wavelengths) for ultrafast optics (10% bandwidth). If proposing an instrument to characterize LIDT, spatial resolution must be better than 1 mm, and the instrument must be capable of mapping a 4 cm diameter aperture, minimum. If proposing a dopant concentration instrument, accuracy must be 0.05 at% or better in the dopant concentration, with a spatial resolution of 1 mm or better. If proposing a wavefront characterization instrument, accuracy must be lambda/10 RMS or better over a 10 cm x 10 cm single field, and the instrument must have the capability to accurately stitch fields together over at least a 100 cm x 100 cm full aperture

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

Return to Table of Contents

d. Fast Feedback Systems for Lasers to Increase Stability and Control

Laser applications to accelerators and other systems demand increased precision. This requires correction for variations in the laser delivery parameters resulting from environmental factors such as fluctuations in temperature, sound, vibrations, changes in duty factor, and humidity. The environmental factors are typically dominated by <100 Hz spectral components (e.g., mirror mounts in the transport may have a vibrational resonance at ~40 Hz) and are thus well-suited to be compensated with fast feedback systems.

Currently, many higher power ultrafast lasers operate at repetition rates below 10 Hz, but typically there are alignment lasers present along the beam line all the way to the interaction point that can be used for control. In the longer term, laser system repetition rates of kHz and 10's of kHz are expected.

Grant proposals are sought to develop fast feedback systems to correct laser parameters such as a transverse position and pointing angle of the laser at the final focus. The complete system would include sensors (non-perturbative), actuators, and a fast control system.

Threshold. Proposals must aim, at a minimum, to provide a pointing stability of better than 2 micro-radian RMS, measured at the final aperture before the laser interacts with its intended target, and must do so under VC-A vibration conditions or worse. Feedback system must recover automatically (e.g., from momentarily blocked laser beam) within 100 msec or 100 laser pulses (whichever is faster) without manual intervention.

Objective. Priority will be given to proposals that also correct 5-100 Hz jitter in wavefront and transverse mode content, with wavefront stabilized to <lambda/10 error across the full optical aperture, and transverse mode content stabilized to maintain Strehl>0.95 under VC-A vibration conditions or worse.

Questions – Contact: Eric Colby, eric.colby@science.doe.gov

e. 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

f. 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

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35. 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 magnets are widely used in particle accelerators for beam steering and focusing. Advanced R&D is needed in support of this research in high-field superconductor and superconducting magnet technologies. This topic addresses only those superconducting magnet development technologies that support accelerators, storage rings, and charged particle beam transport systems and only those superconducting wire technologies that support long strand lengths suitable for winding magnets without splices. 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) $Ba_2Cu_3O_7$ (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:

- property improvement, such as higher current density or higher operating field;
- improved tolerance to property degradation as a function of applied strain;
- 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;
- innovative geometry for ReBCO materials that leads to lower magnet inductance (cables) and lower losses under changing transverse magnetic fields;
- 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:

- very high field (greater than 16 T) HTS/LTS hybrid dipole magnets;
- 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;
- 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. Persistent Current Mode HTS Magnets

Recent advances in the fabrication of HTS coils have enabled novel designs of superconducting accelerator magnets working in a persistent current mode. The temporal stability of persistent mode provides unique advantages. To energize these short-circuited coils requires a primary coil inductively coupled with the HTS coil. Grant applications are sought to develop persistent current HTS coils with critical current density comparable to driven mode coils and decay times less than 20 ppm/hour.

Questions – Contact: Ken Marken, ken.marken@science.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.

Questions – Contact: Ken Marken, ken.marken@science.doe.gov

References: Subtopics a and b:

1. Larbalestier, D., Jiang, J., Trociewitz, U.P., et al. “Isotropic Round-Wire Multifilament Cuprate Superconductor for Generation of Magnetic Fields Above 30 T.” Nature Materials, vol.13, p. 375, 2014, https://www.nature.com/articles/nmat3887

Return to Table of Contents

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References: Subtopic c:

1. Kashikhin, V.S., Turrioni, D. "HTS Quadrupole Magnet for the Persistent Current Mode Operation*." IEEE Trans. on Applied Superconductivity*, 2020, Vol. 30, Issue 4, 4602104, https://ieeexplore.ieee.org/document/9032338

2. J. Kosa, I. Vajda, A. Gyore, "Application Possibilities with Continuous YBCO Loops Made of HTS Wire", *Journal of Physics-Conference Series*, 234:(3), Paper 032030, https://snf.ieeecsc.org/sites/ieeecsc.org/files/EUCAS2009-ST153.pdf

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36. 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. Single Electron Transistors for Exotic Force and Particle Searches

Single electron transistors (SETs) can control the locations of individual electrons with high fidelity and can do so at relatively warm temperatures of 3K and above. These systems are fabricated by large CMOS foundries and offer all the attendant advantages. Although the unit of sensing is a single electron, there is the potential to achieve significantly lower noise level by various methods. External signals can be coupled to the circuitry by electric fields, magnetic fields, light, mechanical force, etc., which may allow novel ways to explore the exotic force and matter parameter space. Proposals are sought to develop SET-based low-noise, cryogenic systems that enable future, more sensitive exotica searches.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

c. 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 higher-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 do 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

d. 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.

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.

Proposals that do not address the required level of radiation hardness will be considered non-responsive.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

e. 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; Fabrication of miniature, ultra-low loss, superconducting resonator arrays; and Electronic frequency tuning mechanisms for microwave resonators.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

f. 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

g. 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

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37. 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 (highly-pixilated, fast readback with position resolution of less than 0.3 mm and time resolution of less than 100 ps), new alkali and non-alkali photocathode materials, and high volume manufacturing of large-area, ultra clean, sealed vacuum assemblies.

For collider and intensity frontier experiments, grant applications are sought to develop and advance the wide-band gap solid-state photodetector technology with internal gain that has low dark current, good radiation hardness, and reduced gain sensitivity to temperature.

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. 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

e. 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.

Proposals that do not address a specific need of a specific HEP experiment will be considered non-responsive.

Questions – Contact: Helmut Marsiske, helmut.marsiske@science.doe.gov

f. 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

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Return to Table of Contents

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38. 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 Low-Temperature Technologies for QIS Systems

Cryogenic QIS systems operating near or below one Kelvin (1 K) are growing in scope and cold mass. 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; (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.

Questions – Contact: John Boger, john.boger@science.doe.gov

b. High Efficiency Photodetectors and Homodyne Detectors

While substantial quantum squeezing and entanglement can be produced optically, high efficiency photodetection in cryogenic and other environments is necessary in order to make use of it. High detection efficiency is also vital to quantum networks of sensors. Proposals are sought for production, testing, and/or validation of photodetector systems with high speed (>5GHz) and high quantum efficiency (>99%) capable of detecting continuous variable quantum information in telecom and NIR wavelengths. In some sensing protocols, coherent detection is required to properly characterize signals and noise and to detect the presence of entanglement in optical fields. High efficiency (>99%) and high speed (>1GHz) homodyne detectors are needed in order to enable advanced sensing and networking applications.

Questions – Contact: John Boger, john.boger@science.doe.gov

c. Technology for Co-existence of Traditional Data and Quantum Information Over Long Distances

In order to most efficiently use resources including optical fiber, there is a need to have quantum states propagate along the same fiber that simultaneously carries traditional data traffic. The presence of traditional data signals can cause various noise and interference effects including Raman scattering and four-wave mixing. Since quantum signals are sensitive to background light levels of <<1 photon, these unwanted effects can seriously limit the amount of optical power that can be launched into the fiber and thereby limit the data rate that can be transmitted. One mitigation technique is to use a classical data wavelength that is much longer than the quantum wavelength. However, there is also the desire to have as low a loss at the quantum wavelength as possible, which is typically near 1550 nm.

This project will study means to allow quantum and classical data to co-propagate over long distances. Any suitable designs including the use or optimization of Raman amplifiers, wavelength engineering, polarization control, modulation format, or any other technique can be considered provided it does not assume time-synchronization between all the channels which is seen as overly constrictive. A metric of the maximum data rate possible over 100 km of fiber propagation to maintain a ratio of quantum signal to classical noise of >10 is one way to assess the overall performance.

Questions – Contact: John Boger, john.boger@science.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.

Questions – Contact: John Boger, john.boger@science.doe.gov

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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 four priority focus areas:
(1) Sustaining the existing fleet;
(2) Getting advanced reactor technologies over the finish line;
(3) Establishing and maintaining critical fuel cycle infrastructure; and,
(4) Enhancing global competitiveness

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 approximately 55 percent of the nation's annual clean electricity production, generates nearly 20 percent of U.S. electricity from a fleet of 94 operating units in 28 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.

39. 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. Wireless Technology for Nuclear Instrumentation and Control Systems (Crosscutting Research)
The Advanced Sensors and Instrumentation program seeks applications to develop wireless instrumentation for nuclear applications, especially for advanced reactors. Currently, electrical cables are critical infrastructure necessary to operate a Nuclear Power Plant (NPP) effectively and safely. A typical NPP has more than 1,000 km of power, control, instrumentation and other cables within the plant and the cost of construction and maintenance is significant. When considering advanced control modes for future

reactor concepts, including microreactors, cables performance degradation in radioactive environments becomes an important limiting factor.

Wireless technology is increasingly deployed for the improvement and cost optimization of several common industrial applications, for example the use of Radio-Frequency Identification (RFID) in the distribution and retail sector. Proposals should consider how technical solutions with proven performance in other applications, outside of the nuclear industry, could be adapted to improve the performance and cost-effectiveness of nuclear systems.

Applicants should focus on the following:

- Develop wireless technology to measure and transmit data on system temperature, pressure, forces, acceleration, vibration, and the health of structural components. Multimodal sensors (i.e., capable of detecting two or more independent parameters simultaneously) or technologies applicable to more than one measurement type should be prioritized.
- Provide clear description of the impact of the proposed wireless technology on the system cost-effectiveness, including fabrication aspects and the integration with advanced control mode if applicable (i.e., supporting autonomous operation) by providing a cost-benefit analysis.

The application should indicate whether and how the proposed technology is or may be applicable to multiple reactors or fuel cycle applications, i.e. crosscutting. Proposals should support the Department of Energy's (DOE) Office of Nuclear Energy's (NE) mission to advance U.S. nuclear power in order to meet the nation's energy needs by: 1) enhancing the long-term viability and competitiveness of the existing U.S. reactor fleet; 2) developing an advanced reactor pipeline, and, 3) implementing and maintaining the national strategic fuel cycle and supply chain infrastructure.

Grant applications that address the following areas are NOT of interest for this subtopic and will be declined: cybersecurity aspects related to wireless transmission, 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: Melissa Bates, melissa.bates@nuclear.energy.gov

For more information on the ASI program visit https://www.energy.gov/ne/advanced-sensors-and-instrumentation-asi-program-documents-resources

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 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.

- Develop and/or demonstrate coating methods capable of coating internal cladding tube surface with metallic zirconium. The thickness of the coating material should be approximately 12-25 µm thick extending at least 1 meter into a 2-meter-long tube. Cladding diameter dimensions are approximately 6.86 mm OD x 0.56 mm wall. It is also important that the coating can be inspected to verify coating thickness along the entire coating length and identify any coating flaws such as scratches or areas of thinner coating.

- Develop and/or demonstrate high temperature (300-600C) pilger processing of tubing for fast reactor cladding applications. Methods are needed to produce thin walled high strength cladding for fast reactor fuel applications out of materials with low tensile ductility. Typical thicknesses are ~0.5 mm and cladding diameters are ~6 mm. Length of tubes are ~3 m. Methods must produce tubes that are free from defects such as cracks or pits. Tubes must maintain a circular cross-section over the length of the tubes.

- Develop and/or demonstrate additive manufacturing methods for producing reactor core materials for fast reactor applications, including ducts or thin walled cladding. Method must produce fully dense materials unless the porosity can be beneficial to the application of the material. Properties of additive manufactured materials need to be equal to or better than the materials they are replacing. Methods could also include the ability to provide a material gradient on the component to join two dissimilar materials.

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. Specifically, MPACT develops innovative technologies and tools which enable the integration of safeguards and security features into the design and operation of nuclear fuel cycles. Examples include processes such as advanced reactor fuel recycling via aqueous or electrochemical means, advanced reactor fuel fabrication, and other process control applications. Grant applications are requested for:

- Inert Hot Cell Gamma Spectroscopy. Medium/high resolution (3-7%) gamma spectroscopy systems that can operate in a dry inert (e.g. Ar) hot cell. Development of such system would assist in hot cell surveys, material location & identification, and potentially material quantification for NMAC.
- Actinide Sensitive Materials Research. Identify and develop materials with actinide-selective sensitivities for advanced fuel cycle applications. These applications may include high temperatures, molten salts, liquid sodium, or liquid lead. Identifying and characterizing materials that may demonstrate actinide sensitivity under these conditions will advance U.S. NMAC capabilities for future reactors by qualitatively or quantitatively indicating actinide concentrations.
- Neutron detectors. Neutron detectors for Nuclear Material Accountancy and Control (NMAC) traditionally are 3He, 10B, or 6Li based due to the large thermal neutron cross section and detector infrastructure that enables neutron multiplicity measurements. However, optimization of these detector designs has not occurred for high rate applications (high neutron, high gamma, or high neutron and gamma). Recent pushes to directly measure Pu in spent fuel have focused on overall system designs, but not sup-component (detector-level) optimization. This optimization has the potential to significantly advance neutron assay with benefits to NMAC needs at the back end of the nuclear fuel cycle (Pu verification in spent fuel, storage, reprocessing, and waste).
- Acquisition electronics for neutron assay systems. Current preamplifiers for assay systems utilize mature technology, but commercially available electronics do not exploit amplifier component advances over the past decade. It should be possible to develop preamplifier electronics that have

1) zero deadtime, 2) effectively discriminate between neutron and gamma pulses, and 3) enable independent neutron and gamma counting with neutron multiplicity capabilities. Additionally, these preamplifiers should be rugged, able to operate under industrial conditions and over a wide humidity range.

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://inl.gov/neams/ to industry problems for increased use by industry, either light-water reactor (LWR) or non-LWR 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 for improved use of fast-running design tools; and
- Provide capabilities for automated verification of numerical solutions, including mesh refinement studies;
- Use 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. Materials Research

1. **Nondestructive Examination (NDE) Techniques for In-situ Monitoring of Cable Insulation**

   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:

- fiber optics for distributed temperature sensing of component local environments;
- on-line spread spectrum time domain reflectometry for circuit health monitoring;
- on-line FDR (frequency domain reflectometry) or JTFDR (joint time-frequency domain reflectometry);
- on-line partial discharge testing for low/medium voltage cables

2. **Develop or Improve Small Scale Mechanical Testing Techniques to Provide Size-independent Material Properties of Alloys in an NPP Environment**
Reactor metallic materials are subjected to a challenging core environment with complex mechanical loads, corrosive coolant, and intensive neutron irradiation during operation. As a result, the mechanical properties and service performance of reactor metals can degrade considerably over time. To assure the long-term sustainability and reliability of light water reactors, the extent of materials degradation must be evaluated quantitatively with well-designed tests and relevant materials. Currently, most mechanical tests require full-scale, engineering-size samples to assure the adequate constraints and statistical significance. This imposes a significant challenge for testing neutron-irradiated materials which are highly radioactive and difficult to handle experimentally. Heavily shielded facilities with strict controls are often required for testing such samples. Thus, mechanical test methods with small-scale samples are highly desirable from both economic and technical stand points. With the rapid development of digital and sensor technologies in recent decades, new opportunities have become available to minimize the test samples. Proposals are sought to develop or improve the mechanical testing techniques to provide tensile, creep, fatigue, impact toughness, fracture toughness, and stress corrosion cracking properties with miniature specimens to provide size-independent material properties. Coordinated effort with continuum models and simulations are encouraged.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

f. Flexible Plant Operation & Generation

In order to assure continued operation of the current nuclear fleet in a climate of challenging economic conditions for many plants, the Light Water Reactor Sustainability, Flexible Plant Operation and Generation program is seeking to enable nuclear plants to develop an alternate revenue source that can provide economic benefit and long-term sustainment. The Department of Energy in association with nuclear plant owners and industrial partners are developing processes and technology that will allow nuclear plants to alternate between electrical power generation and direct energy supply through production of green hydrogen or other energy carriers to industrial manufacturing plants and clean energy users. Flexible plant operation 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. The following areas of technology development are needed:

1. **Improvement of Software Tools**
The Light Water Reactor Sustainability program, in collaboration with Integrated Energy Systems have developed software analytic tools to help ensure long term economic viability of currently operating nuclear power plants. The techno economic analysis needed to validate the examined approaches are challenging and embrace grid modeling, dynamic asset modeling and long-term financial planning.

These tools, developed in collaboration with the Integrated Energy System program, will allow the creation of models and processes to determine the most cost-effective approach to implementing hybrid energy systems.

Additional research is needed to:
- Further mature analytic software tools
- Enable the use of these tools by future customers by improving their usability and connecting them with already existing commercial tools where appropriate
- Adapt the tools to solve specialized problems related to the current nuclear fleet and industrial customers
- Application of the tools to demonstrate value for real-world industry applications

2. **Steam-to-steam Heat Exchanger for BWR Thermal Energy Heat Extraction and Delivery**
Heat exchanger concepts that raise steam using steam with minimal loss of steam quality are needed. The heat exchangers need to mitigate tritium migration to the secondary steam loop that will deliver heat to industrial users, including potential food processing industries, or industries that directly use steam for the production of a non-electricity product. Heat exchangers that adjust to variable flows are needed to support thermal energy dispatch between BWR power production and delivery to the thermal energy user. Developing advanced, well-sealed, heat exchangers or improving their efficiency is consistent with the goals of DOE's Water Security Grand Challenge.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

g. Enhancement of LOGOS and SR2ML
Industry Equipment Reliability (ER) and asset management Programs are essential elements that help ensure the safe and economical operation of nuclear power plants. There is an opportunity to significantly enhance the collection, analysis, and use of this information to provide more cost-effective plant operation.

The Risk-Informed Systems Analysis (RISA) Pathway has focused on the developments of tools (i.e., SR2ML and LOGOS) that can integrate component/system reliability models, cost models, and optimization methods into one evaluation framework. The goal is to employ these tools with the INL developed code RAVEN to manage plant risk (both economic and safety related) and manage plant resources (e.g., activity planning and scheduling). The development of these tools is coming to completion and they are planned to be released via open source in 2021.

The SR2ML is a software package that contains reliability models designed to be interfaced with RAVEN. These models can be used to perform both static and dynamic system risk analysis and determine risk importance of specific elements of the considered system. Two classes of reliability models have been developed; the first class includes all traditional reliability models while the second class includes several component ageing models.

LOGOS contains a set of discrete optimization models that can be used for capital budgeting optimization problems. This tool uses component health information (e.g., failure rate or failure probability), various costs (e.g., maintenance, operations, replacement), and plant budget constraints to provide the optimal set of projects (e.g., component replacement or refurbishment) that maximizes profit and satisfies the provided requirements.

The response to this call should target the enhancement of the INL-developed software tools LOGOS and SR2ML. In particular, applications are sought in one of the following areas:

- Data processing. The developed models require an interface with plant ER to gather information about past plant operational performance. This data can be either text-based (e.g., operations logs, issue reports, work orders) or numerical (e.g., component testing data, prognostics and health management data). There is a need to automatize this collection process such that ER data can be automatically used by LOGOS and SR2ML to manage and optimize plant resources and activities (e.g., schedule maintenance and replacement).
- Platform development. INL has focused on the development of the models and quantitative methods to manage and optimize plant maintenance activities. There is a need to create a front-end computational platform that can simplify the use of the developed models/methods and provide the user with concise and adequate information. The goal is to improve the deployment functionalities of the developed models/methods.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

h. 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:

- Artificial intelligence/machine learning technologies are sought for troubleshooting and diagnosing nuclear plant operational problems to improve the timeliness and effectiveness of response to emergent degraded conditions. These technologies should enable significant savings in engineering and technical support costs. These technologies should be able to integrate into plant processes for automated assessment and correction, including corrective action program, risk management, and work management functions. Further, the technologies should enable third party outsourcing of trouble shooting and diagnosis through data sharing and remote collaboration capabilities.

- Digital twin technologies for operating nuclear plants are sought to reduce costs in plant monitoring and performance deviation detection. These technologies are intended to enhance operational monitoring by detecting anomalies much lower than instrument setpoints, validating them as real plant phenomena verses sensor malfunctions, determining the deviation trend rate, and identifying the degraded component. The technologies will differentiate cascade effects in connected plant systems from the system with the degraded component. The logic of the digital twin will be transparent and immediately available for rapid verification by plant operators and support staff.

- Self-diagnosis and health monitoring technologies for nuclear plant components are sought for elimination of plant surveillances and other forms of periodic testing, enabling exclusive use of condition-based monitoring for applicable classes of plant components. For these components, all credible failure modes will be addressed, with condition status transmitted on a user-specified frequency. The condition information will support real-time risk monitoring and operational determination. These technologies should be able to integrate into plant processes for automated assessment and correction, including corrective action program, risk management, and work management functions.

Questions – Contact: Alison Hahn, Alison.Hahn@nuclear.energy.gov

i. 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 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

j. Advanced Methods for Manufacturing

AMM program is seeking proposals that can enhance the economics and flexibility of the advanced manufacturing technologies: develop and mature manufacturing technologies that facilitate modular designs and the construction, enhancement of the modular manufacturing technologies, and decreased necessity of field modifications.

Example: emerging powder metallurgy techniques for fabricating nuclear components offer many benefits, including part consolidation, reduced requirements for field fabrication and welding, the potential replacement of forging technics for pressure vessels and larger systems, advance construction technics include concrete modularizations and similar concepts.

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

k. Nuclear Science User Facilities

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/

l. Transformational Challenge Reactor

The Transformational Challenge Reactor (TCR) program provides a revolutionary platform to help demonstrate the ability to reduce the deployment costs and timelines for nuclear energy systems. The TCR program will integrate the digital platform for manufacturing, design, and qualification to enable rapid nuclear innovation and to accelerate adoption of innovative advances in materials, manufacturing, and computational sciences.

Proposals are sought to advance the state-of-the-art of applications that support embedment of sensors in critical structures, systems and components (SSCs) for online monitoring. Monitoring of these SSCs beyond scarce, point-wise and low-sampling-rate measurements will significantly boost the data density and enable informed operational decision-making capabilities through enhanced diagnostics and prognostics. Additionally, new fabrication options afforded by additive manufacturing, unleash opportunities that did not exist before, and allow probing directly into materials. While standard measurements, such as temperature and strain are obvious sensing modalities, these options can be expanded through a robust research program. Moreover, these innovations have the potential to bring about a new paradigm for in-service inspection.

Following research topics are of particular interest:

- Testing and development of a qualification plan for structures with embedded sensors
- Wiring and routing strategies within structures with embedded sensors, and outside the structures
- To facilitate use of fiber optics in pressurized systems, glass-to-metal seals that will meet the maximum leak rate limits throughout the entire operational condition of a feedthrough

Questions – Contact: Dirk Cairns-Gallimore, dirk.cairns-gallimore@nuclear.energy.gov

For more information on the TCR program visit https://tcr.ornl.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 develop technologies and tools that will enable nuclear energy system designers, operators and researchers to characterize cybersecurity of instrumentation and control (I&C) components and systems specific to the nuclear energy sector and identify and mitigate cybersecurity vulnerabilities in such components and systems. Technologies of most relevance will: 1) Identify and model the characteristics of a nuclear power plant I&C system under cyber attack; 2) identify the cyber risk impacts of upgrades and maintenance on such systems; and/or 3) facilitate the secure design of future control systems for the existing fleet and advanced reactors.

Proposers' product(s) of interest may provide designers, operators, and researchers with capability to:

- Develop and demonstrate technologies that enable 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.
- Prevent, detect, and respond to cyber attacks in complex and interdependent I&C systems relevant to nuclear facilities. Of particular interest are methods and tools that address supply chain vulnerabilities, common cause and common access cyber attacks, and response and recovery to cyber attack.
- 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

The Integrated Energy Systems (IES) program seeks to maximize energy utilization, generator profitability, grid reliability and resilience, and efficiency of water usage through novel systems integration and process design, using nuclear energy resources across all energy sectors in coordination with other generators on the grid. The IES program, in collaboration with other DOE programs such as Light Water Reactor Sustainability, is developing tools and technologies that will enable nuclear energy systems, both current fleet and advanced reactors, to support multiple revenue streams by incorporating applications beyond grid electricity production, such as hydrogen production, industrial process heat, and water desalination/purification. Key to the success of these systems is the inclusion of reliable integration hardware, and instrumentation that will allow for secure, resilient system control under a range of operating scenarios. The IES program focuses on implementation options for advanced, non-water cooled, nuclear reactor concepts that leverage the availability of high-quality heat to support a range of industrial applications. Proposals that further enhance the technology readiness level of various system components are desired. Concepts may include:

- Compact heat exchangers;
- Heat transfer components that isolate the nuclear system from downstream end users;
- Smart valves and related integration hardware;
- Embedded sensors that support equipment and component health monitoring;
- Data acquisition and management systems that incorporate advanced informatics and decision systems to support optimized system control and ensure cyber secure operation.

Introduction of technologies that reduce environmental impacts, such as water withdrawals, using IES are also of significant interest, consistent with the goals of DOE's Water Security Grand Challenge. Potential supply chain challenges that could be presented by introduction of new technologies in commercial application of advanced reactor based IES should also be addressed as a component of these proposals.

In addition to the focus on system elements and interface technologies, the DOE laboratories have also developed numerous computational tools to support the complex techno-economic analyses needed to validate candidate system design approaches, incorporating grid modeling, dynamic asset modeling, and long-term financial planning. Proposals that focus on further maturing and commercializing these dynamic, system-level analysis and optimization tools, particularly in the area of advanced reactor applications, are of interest. Proposals that would enhance industry utilization of these tools through connection with existing commercial tools, when appropriate and necessary, and increasing the ability to evaluate the potential for nuclear energy to support of a range of industry applications, will also be considered.

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 early 2030'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: Rebecca Onuschak, Rebecca.Onuschak@nuclear.energy.gov

p. Microreactor Applications, Unattended Operations, and Cost-Reduction 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.
- Technologies that can result in significant reductions in microreactor costs that can expand their applications by increasing their competitiveness with other energy sources. The technologies should not be microreactor design specific but may provide microreactor hardware, system, and operation cost reductions.

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. Development of Online Monitoring Technologies for Molten Salt Reactors

Molten salt reactors (MSRs) use a variety of salts, including fluoride and chloride-based salts, as coolants and solvents for actinide-bearing fuel salts. During operation, fission product buildup in the salt impacts the salt redox potential, potentially creating a corrosive environment without proper redox control. Online surveillance of key salt parameters, such as the U3+/U4+ ratio and level of dissolved alloy constituents (e.g., Cr), is necessary to identify changes in salt chemistry and signal the need to implement corrosion control technologies to ensure that the reactor is operating within proper safety limits. Grant applications are sought to develop online monitoring technologies (e.g., spectroelectrochemical probes) capable of extended use in nuclear-relevant molten salts. The technology should possess high precision and accuracy, chemical and materials stability in the working environment, and extended lifetime (e.g., 6 months). For Phase 1 applications, demonstration of the compatibility and stable operation of the technology in molten salts for long durations and temperature cycling is essential. Novel online monitoring technologies that can enable monitoring of key molten salt properties are especially encouraged.

Questions – Contact: Christina Leggett, Christina.Leggett@nuclear.energy.gov

r. Advanced and Small Reactor Physical Security Cost Reduction

Advanced and small nuclear reactors will not be competitive with natural gas plants unless they are able to drastically reduce physical protection costs. Both intrinsic and extrinsic design features should be considered that can significantly reduce either the up-front capital costs or the operational costs. New ideas or past work that has evaluated these types of cost reductions should be considered. Of particular interest is physical protection modeling and analysis that shows how new designs or approaches affect performance metrics. There are also new and novel physical protection approaches being evaluated in the DOE NE R&D programs. Preparation of commercial modeling and simulation tools used for security performance assessments to evaluate those approaches will help nuclear vendors with licensing efforts.

Questions – Contact: Won Yoon, Won.Yoon@nuclear.energy.gov

s. 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

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Return to Table of Contents

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40. 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:

Return to Table of Contents

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 unsaturated concepts (e.g., alluvium, 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

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

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.

Questions – Contact: Prasad Nair, Prasad.Nair@nuclear.energy.gov

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