U.S. Department of Energy

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

Topics

FY 2019
Phase I
Release 2

Version 9, January 23, 2019

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

Schedule

Event	Dates
Topics Released:	Monday, October 29, 2018
Funding Opportunity Announcement Issued:	Monday, December 17, 2018
Letter of Intent Due Date:	Monday, January 07, 2019
Application Due Date:	Monday, February 25, 2019
Award Notification Date:	Monday, May 20, 2019*
Start of Grant Budget Period:	Monday, July 01, 2019

*** Date Subject to Change**

Table of Changes		
Version	**Date**	**Change**
Ver. 1	Oct. 29, 2018	Original
Ver. 2	Oct. 30, 2018	• Topic 13, subtopic f: Updated technical point of contact • Topic 19: Added additional references • Topic 32: Corrected references
Ver. 3	Nov. 06, 2018	• Topic 27, subtopic a: Updated description • Topic 33, subtopic d: Updated description
Ver. 4	Nov. 07, 2018	• Topic 10, subtopic e: Added references
Ver. 5	Nov. 08, 2018	• Topic 28: Corrected superscript in table • Topic 34, subtopic c: Updated email address
Ver. 6	Nov. 21, 2018	• Topic 26, subtopic e: Updated superscript • Topic 28, subtopic d: Updated superscript • Topic 28, subtopic e: Updated superscript • Topic 29, subtopic a: Updated subscript • Topic 29, subtopic b: Updated subscript • Topic 29, subtopic c: Updated superscript and subscript • Topic 29, subtopic d: Updated superscript • Topic 31, subtopic d: Updated superscript • Topic 31, subtopic f: Updated superscript
Ver. 7	Dec. 07, 2018	• Topic 09, subtopic b: Updated technical point of contact
Ver. 8	Dec. 17, 2018	• Updated schedule
Ver. 9	Jan. 23, 2019	• Topic 07, subtopic d: Updated technical point of contact • Topic 23, subtopic b: Updated technical point of contact • Topic 24, subtopic d: Updated technical point of contact

INTRODUCTION TO DOE SBIR/STTR TOPICS

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

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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 tools and technologies that address a need for the cyber security of power systems operations. Selected proposals must include a scope of work that will lead up to, but will not include, the development of a demonstration prototype.

All applications to subtopics under this topic 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.

- Fully justify the future potential for demonstration with an asset owner/operator who is an intended user.

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. This capability must be timely and secure to prevent any interruption in operations. This tool must also not hinder the work that must be done to transition from contingency to normal operations of the energy delivery system.

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

b. Power Systems Settings Security

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

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

References:

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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.

2. ADVANCED SAMPLE REGISTRATION FOR MICROANALYSES

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 analyses 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 complete characterization of material samples. Advances in modern imaging techniques have resulted in unprecedented capability to spatially resolve chemical and physical properties at length scales that span the nanometer to micrometer range. In concert with these microanalytical imaging technologies, significant advances in machine vision approaches have produced highly efficient algorithms for image processing, recognition and manipulation. A grand challenge for analytical imaging technologies is characterization of regions of interest within a material sample using complementary methods, which requires relocating features with high accuracy (e.g., within a few micrometers), and correlating analytical signals from disparate technologies (e.g. reflected light, secondary electrons or ions, x-ray fluorescence, etc.). Such challenges can be addressed via innovative machine vision approaches to index regions of interest within a sample across multiple analytical imaging platforms to enable (i) efficient correlation of analytical images collected by complementary microanalytical techniques and (ii) effective removal or manipulation of sample features (i.e. particulate matter, impurities, etc.).

Grant applications are sought in the following subtopics:

a. Optical Microscopic Correlation to Analytical Imaging Platforms

Machine vision approaches that confidently correlate features in the spatial fields-of-view between optical microscopy platforms and analytical images obtained by SEM, SEM-EDS, SIMS, and other analytical imaging methods. The software developed in this subtopic shall address and automate (i) the type of analytical information that is necessary for accurate correlation, (ii) approaches to correct aberrations resulting in platform-specific images, (iii) indexed correlation between images from at least one analytical imaging system and optical microscopy, and (iv) accurate indexing of features of interest on optical microscopy platforms to resolutions of 1 micrometer (or better). Sample substrates typically require conductive materials such as metal-coated glass, silicon, or carbon and require registration at or better than the 1 micrometer scale.

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

b. Particle Manipulation and Removal for Dispersed Samples

An optical inspection and robust sample manipulation stage is needed for the removal of particulate materials (typical diameters of 1-300 micrometers). The stage shall consist of an optical microscope, with particle / feature manipulation capable of at least 4 degrees of freedom (DOF) – e.g. x,y,z sample movement and z movement of particle removal mechanism – with sub-micrometer reproducible positioning. The 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 chemical and isotopic composition of collected particles. Particles comprised of refractory materials (e.g. SiO_2, Al_2O_3, and similar oxides) are the target materials for this system.

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

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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. Novel HSI Sensor

Concepts for novel analysis tools that maximize the return of information from hyperspectral imaging (HSI) while optimizing analysis time[1] are solicited. Hyperspectral imaging analysis systems can provide mineral and chemical signatures, and concentration of species analysis; therefore, HSI may have applications to many areas of nuclear proliferation detection.

HSI collections produce pixelated, three dimensional, multivariate hypercube data that can be used to determine chemical composition and the physical properties of materials[2]. The high dimensionality of the data sets represent a large computational burden that HSI analysis tools should seek to alleviate. Novel techniques and concepts to extract chemical concentration information over the 300 nm to 2500 nm region are of interest[3].

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

b. Small Sensor Packages

Improved sensing and analysis technologies that can be fielded on compact, unmanned aerial vehicles (UAVs) is solicited. Such portable systems allow for novel multi-modal sensing opportunities.

Multi-modal sensing allows for the gathering of signatures from different phenomenologies. This combined data can give a much more detailed understanding of activities within a geographical area (e.g. accurately locating and identifying chemical or mineral signatures[1]). There is a need to development complimentary sensor packages which meet size, weight, and power (SWaP) requirements imposed during UAV operation. Sensing options may include: synthetic aperture radar (SAR)[2], light detection and ranging (LIDAR), hyperspectral imaging (HSI), infrasound, or radio frequency. Features of these platforms may be: 1. 'plug and play' capability with off-the-shelf systems; 2. on-board analysis of streaming data that can direct the tasking of specific sensors and/or autonomous flight plans; 3. compact relaying of salient signal features; or 4. enhanced sensor systems that require partnering with nearby UAVs[3].

Phase I will be a conceptual engineering design with performance model of a small sensor package and Phase II will proceed to sensor development.

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

c. Vegetation Subtraction Tool

Improved technologies and methods are sought to filter and remove vegetation from remote imagery and other optical data. The removal of vegetation can result in enhanced digital surface models (DSMs); accurate DSMs can be used to determine if and what proliferation activities are present in areas of dense foliage (e.g. under jungle canopies).

Currently, methods to remove vegetation from DSMs based on photographic, light detection and ranging (LIDAR)[1], or synthetic aperture radar (SAR)[2] data are well known. Infrared and RGB have not received as much attention[3]. Of particular interest are tools that can combine disparate data products into one DSM and/or perform vegetation removal operations with minimal user-in-the loop.

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

d. Flora Bio-Indicator

DNN R&D is seeking improved technologies and methods that use native flora specifically sensitive to source emissions from suspected nuclear facilities as in-situ indicators and monitoring mechanisms of facility functional status. Exploiting the native flora will expand the application space of current remote sensing systems to detecting proliferation activity from longer range standoff distances.

In order to use native flora as a bioindicator and monitor of proliferation activity, the exposure-response relationship must be well understood. Therefore, there is a need to develop tools and techniques that will establish the qualitative and quantitative plant response to source emissions[1,2,3]. Potential strategies would involve controlled laboratory exposures coupled with in-situ sampling methods and targeting key plant organelles[4,5,6]. An identified need is the development of near real-time measurement solutions that could be used in-field to confirm plant response to environmental exposures[7,8]. In addition, a secondary confirmation method involving quantitative analytic measurements in a controlled laboratory setting is also considered an essential part of the research and development[9,10].

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

References: Subtopic a:

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1. Burger, J. and Gowen, A., 2011, Data Handling in Hyperspectral Image Analysis, Chemometrics and Intelligent Laboratory Systems, Volume 108, Issue 1, p. 13-22. https://www.sciencedirect.com/science/article/abs/pii/S0169743911000761

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4. ALTERNATIVE RADIATION 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

Reduction of the reliance of high-activity commercial and industrial radioactive sources is a nonproliferation goal. The Office of Proliferation Detection is interesting 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. Compact Cyclotrons for Nuclear Security

While compact cyclotrons have been demonstrated for medical isotope production, a number of challenges remain in the development of a fieldable, commercial system for nuclear security applications.

Proposals should consider the following issues:

- Practical considerations of required ion energies and beam intensities for nuclear security applications including: a) Ion source type, b) Energy of the ions at the extraction point, c) Intensity of the beam.
- Mobility: Considerations that would permit the system to be transportable should be explored. Operation in transit is not a requirement.
- Internal ion source and beam quality are important considerations in the design. Each application dictates the desired beam current, which in turn will affect the selection of the source, including its positioning. An external ion source may be required for higher beam currents, but the complexity and cost for this option should be considered.
- Alternative approaches to perform beam extraction from cyclotrons is desired. Since beam quality and intensity are essential in this application space, the following should be considered: a) Beam deflection/losses at the extraction point, b) Orbit stability and turn separation at the extraction point and effect of beam extraction on inner orbits, c) Fringe field effects at the beam extraction point.

Phase I should produce a conceptual design of a cyclotron capable of satisfying the needs of nuclear security. Proposals should emphasize the importance of compact design without compromising the quality and the energy of the ion beam. Proposals should NOT focus on conversion target design (e.g. conversion of the extracted ions to other particles) other than identifying promising reactions and listing justification for selection a particular material. Phase II should include a detailed system design.

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

b. Non-Radioisotopic Technology for Industrial Radiography

Proposals are sought for the development of an ultrasonic testing device capable of replacing the need for radioisotope source-based radiography cameras.

Industrial radiography is widely used in the chemical, petrochemical, and building industries for radiographic inspection of pipes, boilers, and structures where the economic and safety consequences of failure can be severe. Multiple radiography technologies are available, with radioisotope sources, non-radioisotopic x-ray sources, and ultrasonic testing sources in wide use. The use of high-activity radioisotope sources (including 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 ultrasonic testing have the potential to be used in lieu of radioisotope sources, thus eliminating the security risk. However, the technology needs to be improved to overcome its current deficiencies.

The device needs to be very mobile and robust to challenging environmental conditions, including cold temperatures where the coupling fluid that is currently used fails to operate. The device should employ novel methods to identify material defects that have previously been challenging for ultrasonic testing, including narrow defects that are aligned with the sound wave, shallow surface defects, and porosity variations. In addition, the device should include improved analysis software to make the ultrasonic scans easier to interpret, requiring less technician training than currently available ultrasonic testing devices. The device should be reliable, robust, and cost competitive with gamma radiography cameras.

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

c. Non-Radioisotopic Irradiation Technology to Enable Sterile Insect Technique

Proposals are sought for the development of a self-shielded irradiator that is ideally suited to insect irradiation in support of the Sterile Insect Technique.

Sterile Insect Technique is a method of insect pest control by which target insects (typically males only) are reared in mass, rendered sterile, and released to compete with wild insects in a target region. If sufficient numbers of wild females mate with sterile rather than fertile males, the target insect population will be reduced. One common method of insect sterilization is exposure to ionizing radiation, typically from radioisotope sources (e.g. Co-60 or Cs-137). The use of high-activity radioisotope sources poses a radiological security risk since the sources could be stolen and used in a radiological dispersal device, or “dirty bomb”. Therefore, the use of non-radioisotopic sources (e.g. x-ray or electron beam irradiators) in lieu of high-activity radioisotope sources supports radiological security by eliminating the risk of radioisotope source theft and misuse.

The device needs to be capable of high throughput processing, preferably including a conveyer system. A device that can be installed in-line with the insect processing equipment would be ideal. The device must meet the dose delivery and dose uniformity requirements for SIT applications: typically 20 – 500 Gy and a

Dose Uniformity Ratio below 1.5, preferably below 1.3. The device needs to be reliable, robust, and sustainable in challenging operating conditions including unpredictable electrical power, environmental control (temperature and humidity), and water supply systems. The device should be easy to operate and maintain, and be cost competitive with existing radioisotope source-based irradiators.

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

d. Other

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

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

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PROGRAM AREA OVERVIEW: OFFICE OF ELECTRICITY

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

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

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

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

5. ADVANCED GRID OPERATIONAL 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 (e.g., coal, nuclear) to smaller units (e.g., gas-fired turbines) and variable energy resources (e.g., renewables). On the demand-side, there is a growing number of distributed energy resources, as well as the increasing use of electronic converters in buildings, industrial equipment, and consumer devices. The monitoring, control, and protection systems used for grid operations are also transitioning from analog systems to systems with increasing data streams and more digital control and communications; from systems with a handful of control points at central stations to ones with potentially millions of control points. In essence, the grid we have today was not designed for today's requirements and will demand next-generation grid operational technologies.

All applications to subtopics under this topic should:

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

Grant applications are sought in the following subtopics:

a. Blockchain Technologies for the Electric Grid

Blockchain technologies have the potential to address electric system challenges in operations, markets, and grid information and communications technologies (ICT). There are multiple blockchain offerings in development today with many approaches for achieving consensus between peers in a decentralized, distributed peer-to-peer network; some are private and permissioned while others claim to be fully decentralized and permission-less. However, there have been limited instances where blockchain technologies were utilized to enhance grid reliability and resilience.

Despite recent advances, many technical challenges remain in applying blockchain technologies to the electric grid. For example, many consensus mechanisms have limitations such as energy-intensive proof of work, and the energy per transaction needs to be accurately quantified and reduced to an acceptable level. Additionally, scalability to a sufficiently large number of nodes, depending on the application scenario, has yet to be demonstrated in practice. Heterogeneity of nodes, either due to differences in vendor hardware or type of blockchain used, presents yet another hurdle.

All applications to this subtopic should consider:

- Open source software/architectures that preserve the salient features of blockchain technologies such as immutability and decentralization;
- Compatibility with existing grid infrastructure and associated communications protocols such as DNP3; and
- Compatibility or complementarity, if applicable, of proposed blockchain with databases such as influxdb, OpenTSDB, and IPFS, and how the blockchain's functionality might be augmented with such technologies.

All applications must include a full description of blockchain properties including: blockchain type (e.g., private and permissioned vs. public and trustless); consensus mechanism; block size in MB; how the data is secured at the source after origination and during transport, before being validated and embedded in a block; whether full nodes or partial nodes are being used; extent of logical and physical decentralization; quantitative information on block latency as it relates to the use case needs; network latency due to infrastructure; requirements in terms of processor, memory, and bandwidth; known blockchain attack vectors with risk mitigation plans; and cybersecurity properties and functions (e.g., device access and authentication, message integrity, confidentiality, and non-repudiation).

Additionally, all applications should discuss how the solution can be applied to at least one of the following use cases:

- A low-trust, high-integrity peer-to-peer (i.e., customer-to-customer and customer-to-utility) transactional network for energy or other grid services with incorporation of both static and dynamic grid constraints. Grid constraints include but are not limited to congestion, physical or operational limits of equipment or conductors, and electrical connectivity (e.g., feeder reconfiguration that creates or eliminates conductive paths between prospective transacting entities).
- Distributing securely and maintaining high-integrity of asset firmware or configuration information for distributed applications (including preservation of current and prior applications). Assets encompass substation hardware (e.g., power transformers, RTU's, protective relays, PMU's) and field hardware (e.g., distribution transformers, reclosers, capacitor banks, meters), and may extend to customer-owned assets.

- Enhancing the integrity and immutability of sensor data and data transport from the point of origination to centralized datastores at the utility. Data availability at individual endpoints, among nodes at the distribution feeder and distribution substation level (as required by distributed data environments such as Open Field Message Bus), and at the utility head-end must be discussed. Data integrity prior to and after incorporation into a blockchain must also be discussed.

For the use cases, scalability must be demonstrated up to a distribution substation comprising of 3 to 8 distribution feeders serving a mix of commercial and residential customers with a total customer count between 500 and 5,000 and a total ICT asset count of 10,000. Scalability to multiple distribution substations and beyond are encouraged.

Questions – Contact: Christopher Irwin, Christopher.Irwin@hq.doe.gov

b. Advanced Protective Relaying Technologies and Tools

IEEE defines a protective relay as "a relay whose function is to detect defective lines or apparatus or other power system conditions of an abnormal or dangerous nature and to initiate appropriate control circuit action." As the electric power system continues to evolve, there are several challenges that require advances in protective relaying solutions to ensure the safe and reliable operation of the grid.

Protective relaying technology has evolved from being based on electromechanical devices, to solid state, and more recently microprocessors. While the technology has increased in accuracy and functionality, there has also been a reduction in their life expectancy. Reasons for the shorter life range from thermal effects of power supplies to contact material degradation. Cybersecurity attacks could also cause improper relay operations, jeopardizing the operational integrity of the electrical system.

Another concern deals with greater penetration of distributed energy resources (DERs) that can result in reverse power flows in the distribution system. Protective relay set-points are based on the assumption that the utility will supply fault currents but the contributions from DERs may result in failure to operate. Other examples of misoperations can be found in the NERC Glossary of Terms (see references).

Ultimately, degraded relay performance due to age, improper settings, misoperations, and inaccuracies present a hazard to the public and utility workers. This subtopic is looking to develop technologies, methodologies, processes, materials, or tools that will advance the state of the art of protective relaying.

Desired characteristics and capabilities include:

- Longer life spans (e.g., 30-40 years)
- Dynamic, adaptive set-points
- Self-diagnostics
- Lower costs
- Detection and prevention of misoperation
- Improved fault detection and location

Collaboration with protection device manufacturers and utility protection engineers is strongly encouraged.

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

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6. ADVANCED GRID-TIED ENERGY STORAGE 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

Grid-tied energy storage systems (ESS) are becoming more prevalent in the electric grid, helping to improve the reliability, security, flexibility, resilience, and cost-effectiveness of the existing and future electric infrastructure. ESS trends are moving towards systems that include the energy storage technology and power electronics in an integrated package (e.g., standard shipping container) for ease of transport, siting, and installation. Smaller form factors present unique challenges for the power conversion system (PCS) and the energy storage technology. Challenges include high power density designs, increased efficiency and reliability, reduced thermal management requirements, and low costs. Additionally, high power density designs need special considerations to ensure safe and reliable operations.

All applications to subtopics under this topic should:

- Be consistent with and have performance metrics (whenever possible) linked to published, authoritative analyses in your technology space.

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

Grant applications are sought in the following subtopics:

a. Battery Systems for Energy Assurance During and After Extreme Weather Events

Power outages and interruptions cost the U.S. economy $79B/year and can threaten public health and safety. During and after extreme weather events that result in wide area or extended grid outages, fossil-fueled generators are typically used as a source of power. However, availability and transportation of fuel may be difficult and expensive in these situations. Various battery technologies can be used as an alternate to portable generators with different cost and performance implications. For example, li-ion batteries can last for many charge-discharge cycles but are expensive, dangerous to transport in bulk, and prohibited from air-lifting; alkaline batteries are inexpensive, have high energy density, long shelf-life, and come in a charged state but they cannot be recharged; and lead-acid batteries are affordable but require trickle charging and cannot be stored in a charged state.

Rechargeable battery systems are desired that are:

- cost-competitive with conventional generators
- easily transported and installed at houses, businesses, or communities
- low-hazard and safe for rapid deployment
- maintains a charged state for at least 5 years (i.e., long shelf-life)
- durable and robust (e.g., multiple cycles, no special cooling or heating equipment)
- hardened (e.g., holds charge and works over a wide temperature range, operates in extreme weather conditions)
- adaptable (e.g., can be charged from the grid or non-grid sources such as distributed energy resources)
- system energy density greater than 100Wh/L
- at a minimum, provides 15 kWh/day for two days per household

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

b. Advanced Circuit Topologies for Reliable Grid-Tied Energy Storage Systems

The ESS PCS controls the power supplied and absorbed from the grid to optimize energy storage device performance while potentially providing grid services. Wide band gap (WBG) semiconductor switches have gained significant interest in the past decade due to increased breakdown voltages, faster switching speeds, and higher junction temperatures compared to their silicon counterparts. While WBG switches are key to next-generation PCSs with high efficiencies, WBG material and device fabrication technologies are not as mature, and the resulting devices are relatively vulnerable to various degradation mechanisms.

Changing the way PCS are designed, monitored, and controlled can improve WBG switch performance and increase reliability, making the most of devices that are available today. For example, advanced sensing and controls can apply restorative electrical stresses on specific switches depending on the level of degradation. Advanced circuit topologies with in-situ restoration capabilities for next-generation, high-reliability ESS are sought.

Suitable designs will be able to operate switches at or beyond the specification limits of frequency, temperature, and blocking voltage while maintaining expected performance parameters. For example, drift in device parameters such as threshold voltage, breakdown voltage, leakage current, and on-resistance should not exceed 1% over the life of the system (i.e., 25 years with availability > 99.9%, efficiency > 98%, and THD < 2%) under typical use conditions (e.g., nominal switching frequency, junction temperature up to 175°C).

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

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PROGRAM AREA OVERVIEW: OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

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

7. ADVANCED MANUFACTURING

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

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

Applications must:

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

Grant applications are sought in the following subtopics:

a. Manufacturing Cybersecurity

Manufacturing is most vulnerable to cyber-attacks and disruption to processes, rather than to data – and among manufacturing systems, industrial controls have been identified as most vulnerable. [1, 2] This issue is especially important for small and medium-sized manufacturing enterprises, which usually buy and use commercial control technology and lack personnel dedicated to maintaining control system integrity. Furthermore, many control systems in use in US manufacturing are older and are not easily upgraded due to cost and the need for a smaller manufacturer to maintain production without interruption.

This SBIR topic provides the opportunity for small businesses to work with industrial control developers, vendors, suppliers, standards organizations, and end users to raise situational awareness of existing encryption technologies and investigate and develop cost-effective technology solutions that fill gaps in these existing technologies to reduce industrial control vulnerability. NIST has identified cybersecurity technology gaps for manufacturers. Some of these gaps point to development of new solutions. [3] End users of special importance are small to medium-sized manufacturing enterprises that typically buy commercial control technology for their use and do not have the means to develop technology to ensure control security. Phase I grant applications for feasibility research are invited for the following subtopic areas:

- Identify gaps in existing encryption technology for digital control and/or propose new solutions to protect the data in transit or at rest [4]: Many control loop signals are typically digitized at some point in manufacturing operations. Digital control is provided directly by Direct Digital Controllers DCC or Programmable Logic Controllers PLC. These controllers do not typically come with encryption technology, making digital signals susceptible to exploitation. Phase I exploratory investigations for the development of digital control encryption solutions that involve existing technology are invited, especially for technology directed to legacy digital control circuitry that was not provided with encryption capability originally.
- Technology for situational awareness in legacy control systems: Manufacturing process corruption could appear as complete process disruption, or more insidiously through willful changes introduced almost imperceptibly over time. Phase I grant applications are invited for investigations in technology development for legacy control system situational awareness using real-time or near-real-time data to detect anomalous conditions within a certain condition. Such technology is especially important for critical precision applications such as computer numeric controls applied in discrete parts manufacture.
- Identify gaps in existing wireless sensor signal encryption and propose new solutions: Most wireless sensors in industrial applications do not provide an encrypted signal to the control element or the controller. Those applications are vulnerable to willful disruption or distortion. Encryption would protect the integrity of the control system. Phase I grant applications are invited for wireless sensor encryption solutions that involve existing technologies, and it is expected that investigators will work with appropriate standards and communications authorities for technology development that can be commercialized successfully.

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

b. Atomic Precision for Gaseous Separations

Atomically precise is defined as: Materials, structures, devices, and finished goods produced in a manner such that every atom is at its specified location relative to the other atoms, and in which there are no defects, missing atoms, extra atoms, or incorrect (impurity) atoms. Thus, we are targeting extraordinary materials that are essentially defect free. As deposition processes cannot produce defect-free structures, the only currently available assembly method is to design molecules that self-assemble into defect-free molecular layers. Proposals for methods that do not synthesize membranes using molecular self-assembly will be declined without review. Graphene-based layered membranes are explicitly excluded and proposals for graphene membranes will not be considered to be responsive.

We seek to further advance the development of this new class of strong, thin, and atomically precise membrane materials for separations that provide a 10X permeance improvement over State-of-the-Art polymer membranes. They would have thicknesses generally below 10 nm for high permeance, incorporate atomically precise molecular pores for 100% selectivity, be atomically flat to prevent fouling, and heavily cross-linked for environmental stability. These membranes offer the potential to provide game-changing process energy advances.

The subtopic seeks proposals focused on the separation of gases. The separation of gases into high value products can be game changing for a variety of energy applications. In principle, a series of membranes of sufficient selectivity could separate air into its raw components of N_2, O_2, Ar, CO_2, Ne, He, etc. for US manufacturing of high value products at a competitive advantage. Helium could also be effectively separated from particular natural gas sources where it is concentrated (in the Great Plains, for example) without the need for energy intensive cryogenic treatment. Ethane and propane could be separated from natural gas at low energy cost and sold profitably without the need or infrastructure for cracking, and CO2 could be removed from natural gas with low energy consumption to improve its heating value. CO2 could also be recovered from combustion gases at the source and reused as carbon feedstock for transformation to high value hydrocarbons [1-4].

Responsive proposals will (a) provide evidence that the respondent has the experience and capability to design atomically precise membranes via molecular self-assembly, (b) outline the approach to the molecular design, (c) include milestones and deliverables for physics-based modeling of the membrane, and (d) ideally provide for some synthesis and testing of the design. Whether or not a fully functional membrane is proposed for Phase I, there should be some chemical synthesis component to test out a key aspect of the approach; that is, this is not intended to be a "paper" study only. As this is a novel approach to the separation of gases, wider system design issues may also arise; these may be included as part of a proposal, but the main emphasis must still be on the novel molecular design.

Questions – Contact: David Forrest, david.forrest@ee.doe.gov

c. Covetic Processing of Critical Materials and Strategic Materials

Covetic nanomaterials are metals in which a network of graphene ribbons and nanoparticles has been created using an electrical conversion process in liquid metal [1-5]. Unlike ordinary graphene, the covetic phase exhibits exceptional stability – it persists after remelting and it resists being burned off in the ASTM E1019 method for carbon analysis. Covetics can conduct heat and electricity more efficiently than conventional metals and appear to be more oxidation resistant. Covetic nanomaterials are likely to be commercially important because the process is inexpensively scalable to tonnage quantities. This implies the potential for widespread usage in thousands of energy production, transmission, and storage applications, and to improve energy efficiency for U.S. manufacturing. Cross-cut: The process is of interest to the Advanced Manufacturing Office because it can be performed on a wide range of commercially important critical materials and strategic materials and because it represents a leading-edge opportunity for US manufacturers. Key technical hurdles need to be addressed and low volume high-value-added applications need to be identified and pursued to introduce covetics into commercial production. Areas of particular interest include:

- Application development: We seek advances in covetic alloy development for low volume, high value-added applications as an entrée to commercialization. This may involve critical materials such as rare earths, strategic materials [6] such as lithium and hafnium, high value alloys, or precious metals. We would like to see the process performed on previously unexplored elemental metals and alloys that make commercial sense. The proposed development effort should identify the low volume, high value-added target alloy and application, quantify the commercial potential, specify a plan for conversion and chemical analysis, and include the thermophysical and mechanical property tests to be conducted. The composition and amount of physical material to be made should be explicitly proposed. The processing of that material should be explicitly proposed, including conversion parameter windows, and particularly thermomechanical deformation parameters and heat treatment. AMO recognizes that there are a limited number of laboratories with the capability to make these materials. Applicants should already have some experience in working with covetic nanomaterials or be partnered with those with experience. Proposals with applicants claiming the ability to make covetics, without prior proof of conversion (including enhanced thermal and electrical conductivity), will be declined without review.

- Chemical analysis: We seek advances in the ability to inexpensively analyze the levels of converted and unconverted carbon in covetics. ASTM E1019 does not seem to be effective in measuring the covetic phase [3], and there is an unresolved controversy in this method's ability to distinguish converted vs. unconverted carbon. GDMS also does not seem to be effective. Carbon analysis using Energy Dispersive Spectroscopy on SEM samples is susceptible to chamber contamination, can be expensive, and cannot distinguish between converted and unconverted forms. The same goes for XPS, with the additional problem of poor statistics from small sample size. Raman and EELS can detect the graphene form but cannot provide good statistics on bulk concentrations because of the small sample volumes being measured. DC PES requires a full analysis of all trace elements, may be highly inaccurate at low carbon concentrations, and cannot distinguish between converted and unconverted forms of carbon. Responsive proposals should include a systematic approach (and novel techniques) to determine total carbon, unconverted carbon, and converted carbon. Specific metallurgical alloys or elements should be proposed with a justification for the expected successful outcome. We seek novel techniques, perhaps taking advantage of unique strong binding between the metal matrix and nanocarbon phase. AMO recognizes that there are a limited number of laboratories with the capability to make these materials. Applicants should already have some experience in working with covetic nanomaterials or work with those with experience in order to obtain reference samples.
- Process development: Laboratory synthesis of covetics has proven to be less than straightforward, with inconsistent conversion yields and wide variations in resultant properties. Batch conversion methods will not necessarily scale well to continuous production methods, and a “re-invention” of the process may be required in that case. We seek proposals that address fundamental improvements to the conversion process based on known issues and principles of physics and process metallurgy. These issues should be made explicit in the proposal. Applicants should have appropriate IP positions and agreements in place to proceed with process innovations. Responsive proposals will provide a clear exposition of the fundamental process issue, why this is a problem, and how the proposed work will address the issue and improve and advance the capability of the covetic conversion process. Upgrades to equipment infrastructure will be considered as part of the proposed work. Proposed experiments to verify process improvements must include appropriate plans to measure improvements in conversion effectiveness. A design of experiments approach to optimize process parameters will not be considered responsive to this solicitation.

Questions – Contact: David Forrest, David.Forrest@ee.doe.gov

d. TECHNOLOGY TRANSFER OPPORTUNITY: Electrochemical Recycling Electronic Constituents of Value (E-RECOV)

About 60 percent of the eight million tons of electronic waste generated annually in the U.S. end up in landfills. This electronic waste represents a significant feedstock of valuable base, precious and rare earth metals. Current electronic waste recycling efforts are primarily focused on only precious metal recovery. Processing facilities are located overseas where unsustainable acid leaching or toxic smelting processes are used, and in many cases lack environmental and worker safety controls. There is a growing need to employ safe, cost effective processes within the U.S. to capture all valuable (and in some cases strategic) materials from electronic waste streams. Such technologies enhance the security of the American people by limiting the dependence on foreign supplies of these materials while also creating new opportunities for American manufacturing.

Researchers at Idaho National Laboratory have developed a novel electrochemical process to safely dissolve non-ferrous metals from electronics leading to more complete recovery of recyclable materials while requiring up to 75 percent less chemical reagent than hydrometallurgical processes of comparable scale. The E-RECOV process efficiently recovers the base metals (copper, tin, zinc and nickel) thus allowing precious metals (silver, gold and palladium) to be recovered more efficiently using industry standard methods. The E-RECOV process continuously regenerates the initial oxidizer at the anode, giving the process solution a long life, resulting in significant savings in reagents and waste treatment. The result is reduced chemical use and production of multiple value products. There are options to recover rare earth elements if the feedstock contains appropriate content.

This Technology Transfer Opportunity seeks to leverage an electrochemical process and associated novel system of reactors to recover metals from electronic waste developed at Idaho National Laboratory, under funding from the Critical Materials Institute. The ideal candidate for this TTO opportunity will have an expertise in sourcing specific electronic waste such as printed circuit boards, knowledge of abrasive feedstock size reduction and processing and a knowledge of implementation of hydro and electrometallurgy-based processes. The targeted outcome will be demonstration and scale up of the process to remove metals of value from electronic waste streams.

Idaho National Laboratory Information:
Licensing Information:
License type: Exclusive or Non-Exclusive, please include description of intended field of use in proposal.
Patent Status:

- U.S. Patent No. 9,777,346
  Methods for Recovering Metals from Electronic Waste, and Related Methods
  Issued October 3, 2017.
- U.S. Patent Application No. 15/690,717
  Methods for Recovering Metals from Electronic Waste, and Related Methods
  Filed October 30, 2017.

Questions – Contact: Jonathan Cook, jonathan.cook@inl.gov and David Forrest, David.Forrest@ee.doe.gov

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3. Forrest, D. R., Jasiuk, I., Brown, L., Joyce, P., et al, 2012, Novel Metal-Matrix Composites with Integrally-Bound Nanoscale Carbon, Technical Proceedings of the 2012 NSTI Nanotechnology Conference and Expo, NSTI-Nanotech 2012, p. 560-563. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA559436

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8. BIOENERGY

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

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

All applications to this topic must:

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

Grant applications are sought in the following subtopics:

a. Cell-Free Biochemical Platforms to Optimize Biomass Carbon Conversion Efficiency

The Bioenergy Technologies Office is interested in expanding the use of cell-free systems to further upgrade cellulosic sugars, lignin compounds, and other waste streams into biofuels and bioproducts. Cell-free biosynthesis technologies are a means of utilizing biocatalysts (enzymes) to perform complicated biochemical reactions that often cannot occur with industrial inorganic catalysts. As a historical example, cell-free systems have been used to convert cellulose into glucose for the production of ethanol [1].

Cell-free biosynthesis technologies offer unique advantages compared to conventional microbial fermentations. These include the ability to:

- Direct higher fractions of carbon to product as opposed to cell maintenance thereby increasing yield [2];
- Obviate the risk of producing or accumulating toxic intermediates to the cell [3];
- Reduce capital costs and increase operational throughput by implementing novel reactor designs [4];

- Create de novo synthesis pathways by "mixing and matching" of enzymes and/or lysates from different organisms [5].

Significant challenges exist prior to these types of technologies being expanded to the applications described above. At the recent Cell-Free Synthetic Biology and Biocatalysis Listening Day (https://www.energy.gov/eere/bioenergy/cell-free-synthetic-biology-and-biocatalysis-listening-day), participants identified several key technical barriers that need to be overcome. These technical barriers, enzyme stability, cofactor regeneration, and novel enzyme production hosts and purification strategies, make up the three areas of focus for this subtopic. Applications to this subtopic should address only one of these focus areas in their proposal.

Area 1, Enzyme stability: Enzyme stability represents a significant technical and economic hurdle to technology development in this space. Without enzymes or lysates that are stable on the order of weeks, significant fractions of carbon will otherwise be used in generating the biocatalysts required of these systems. If the enzyme(s) are being scaffolded, the enzyme stability should be demonstrated in this context.

Area 2, Cofactor Regeneration: Inherent to cellular fermentations is the need to balance reducing equivalents (NADH and NADPH) which is achieved through the conversion of pyruvate to Acetyl-CoA, ferredoxin reductases, etc. Equally important are methods to perform adenosine triphosphate (ATP) replenishment in the cell-free system. It is simply not economically feasible to supplement a cell-free system with these compounds, so they need to be sustained in-vitro. Opgenorth [2] describes one such method of balancing these cofactors in order to have these available for subsequent enzymes.

Area 3, Novel enzyme production hosts and purification strategies: Current cell-free systems rely largely on the bulk production of enzymes using E. coli as a host. As such, the range of enzymes and lysates is limited to those that can be successfully heterologously expressed in E. coli.

General Requirements:

- Proposed systems must utilize cellulosic sugars, lignin, or wet waste streams as the primary feedstock to produce biofuels or bioproducts. Proposed systems can also utilize biological intermediates as starting materials (e.g. acetate, pyruvate, butyrate, etc.).
- Applications must address the current state of the art for the production of their target biofuel or bioproduct. At a minimum they need to identify the titer, rate, and yield.
- Product yield calculations need to account for the substrate that is used to produce the purified enzymes and/or lysate.
- By the end of Phase I, projects must have a strategy for eliminating the need for exogenous cofactors (e.g. ATP, NADH, etc.).
- Methods for enzyme purification from the original host must be considered as this can constitute significant costs.

Questions – Contact: David Babson, david.babson@ee.doe.gov

b. Reshaping Plastic Design and Degradation for the Bioeconomy

Plastics are a hallmark of modern life and consumer use of plastics is projected to grow over the coming decades, yet only about 2% of plastics like bottles are recycled into the same or similar-quality applications [1]. This subtopic will focus on two areas of R&D: Designing Plastics for a Circular Carbon Economy and

Reimagining Plastic Degradation for Upcycling. Applicants should address only one of the R&D focus areas in their proposal.

Area 1: Designing Plastics for a Circular Carbon Economy
Modern plastics need to be designed and manufactured with recyclability in mind. Biobased feedstocks are well-suited for designing the plastics of the future due to their composition and structure. Unlike traditional feedstocks, which contain primarily carbon-carbon and carbon-hydrogen bonds, biobased feedstocks contain cleavable oxygen linkages which could be incorporated into the design of new plastics, essentially introducing "zippers" that allow for facile deconstruction at the end of the product's life [2]. In addition, biobased feedstocks can allow access to chemical structures which are not economical to access from petroleum, potentially providing new avenues to access performance-advantaged materials with novel properties. The Department of Energy is seeking proposals targeting bio-derived plastics designed with end-of-life considerations in mind that can enable a circular carbon economy.

Other considerations include:

- Proposed systems must utilize bio-based feedstocks including lignocellulosic biomass, cellulosic hydrolysates, and other lignocellulose-derived intermediates. Feedstocks used for feed or food will be deemed unacceptable.
- Proposals must discuss end-of-life considerations and thoroughly explain the proposed material's advantages over petroleum derived materials. This includes methods to quantitatively characterize of the end-of-life properties of the proposed material.
- Proposals are encouraged to explore performance-advantaged plastics that in addition to superior end-of-life considerations can outperform traditional plastics for a specific, chosen application.

Area 2: Reimagining Plastic Degradation for Upcycling
Only a small fraction of the 60 million tons of plastic used in the United States is recycled, and an even smaller fraction is made into similar quality products as the original plastic, due to a loss in material properties during the recycling process [3]. The rest of plastic waste typically ends up in either landfills or the environment, causing ecological damage. Better methods are needed to address the large waste-disposal problem presented by currently used plastics. This topic will focus on ways to remake our current systems for plastic disposal and recycling with a focus on utilizing an array of plastics as feedstocks for value-added applications. The Department of energy is seeking proposals exploring challenges in selective C-O, C-N, and C-C chemistry, crystallinity, feedstock contamination, breakdown rate, and other innovative ideas to address difficulties with plastic degradation and upcycling. Proposals are encouraged to target systems with low energy requirements as opposed to systems like gasification which have previously been thoroughly investigated for these feedstocks [4].

Other considerations include:

- Proposed systems must target waste plastic streams including but not limited to polyethylene, polypropylene, polystyrene, polyethylene terephthalate, polyurethanes, nylons, polyamides, and polylactams.
- Proposals are encouraged to target mixed or contaminated waste plastic streams with their eventual system configurations, though this is not required for Phase I.
- Proposals are encouraged to target value-added output streams, for example compounds that are more valuable than mixed polymer-derived monomer streams, though this is not required.
- Chemical and biological processes are both of interest.

Questions – Contact: Jay Fitzgerald, jay.fitzgerald@ee.doe.gov

c. Algae Engineering Incubator

BETO's Advanced Algal Systems subtopic, "Algae Engineering Incubator" is intended to identify potentially impactful ideas that are not meaningfully addressed in the subprogram's current project portfolio. The subtopic will be open to all applications that propose the development of technologies that facilitate the goals of the Advanced Algal Systems R&D subprogram through non-biological, engineering approaches. Applicants can review the 2017 Peer Review [1] and 2015 Peer Review [2] reports to identify what non-biological, engineering R&D has already been funded in the portfolio.

The scope for this subtopic is intentionally broad. Examples of proposals that fit this subtopic are the development of equipment that improves laboratory experimental throughput or data quality, the creation of technologies that assist in monitoring and automation of cultivation, and the testing of new materials to reduce the capital expenses of cultivation systems.

Applicants should clearly describe how they will meet the Advanced Algal System's goals or how success of their project will facilitate the success of performers in BETO's algae portfolio.

Applications specifically not of interest:

- Applications that propose to conduct R&D that was the primary focus of previous funding opportunities. Examples of work supported by previous funding opportunities are:
    - Recovery of nutrients from conversion to recycle back to cultivation;
    - Development of harvest/processing technology;
    - Development, characterization, and valorization of finished biofuels and bioproducts from algal biomass;
    - Research on biological improvements, including engineering of strains and cultivation ecology;
    - Research on increasing carbon utilization efficiencies of algal cultivation as well as on developing direct air capture technologies.
- Applications that propose to develop technology that relies on purely heterotrophic algae cultivation.
- Applications that propose mixotrophic algae cultivation strategies that utilize food-based sugars (i.e., derived from food-based crops including but not limited to corn, beets, sorghum, and sugar cane).
- Applications that propose to develop technology for the artificial lighting-based cultivation of algae for energy products (other than as an enabling tool for high throughput laboratory-based screening).
- Applications that propose to work on biomass other than algae biomass (e.g. lignocellulosic biomass, non-algae microorganisms, fungi, etc.).

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

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2. Bioenergy Technologies Office, 2015 Project Peer Review, U.S. Department of Energy. https://www.energy.gov/eere/bioenergy/peer-review-2015

9. BUILDINGS

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

Residential and commercial buildings account for more than 40% of the nation's total energy demand and 70% of electricity use, resulting in an annual national energy bill totaling more than $380 billion [1, 2]. The U.S. Department of Energy's Building Technologies Office (BTO) (http://energy.gov/eere/buildings) is working in partnership with industry, academia, national laboratories, and other stakeholders to develop innovative, cost-effective energy saving technologies that could lead to a significant reduction in building energy consumption and enable sophisticated interactions between buildings and the power grid. BTO's goal is to reduce aggregate building energy use intensity by 45% by 2030, relative to the consumption of 2010 energy-efficient technologies. The rapid development of next-generation building technologies are vital to advance building systems and components that are cost-competitive in the market, to meet BTO's building energy use reduction goals, and lead to the creation of new business and industries. Moreover, by cutting the energy use of U.S. buildings by 20%, the American people could save approximately $80 billion annually on energy bills.

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

Grant applications are sought in the following subtopics:

a. Next Generation Residential Air Handlers

According to ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), an air handler, or air handling unit (AHU), is a Heating, Ventilation and Air-conditioning (HVAC) device that regulates and circulates air. BTO seeks to accelerate the development of the next generation Heating, Ventilation, Air-conditioning, and Refrigeration (HVAC&R), water heating and appliance technologies. HVAC&R technologies consume more than half of the total energy used in U.S. residential and commercial buildings [1]. HVAC alone is the largest energy end-use for U.S. buildings, consuming approximately 40% (15.5 Quads) of total energy in 2015. BTO has published several reports on the energy savings potential and RD&D Opportunities for both Residential and Commercial Building HVAC Systems [2]. These reports document energy efficiency improvements in residential HVAC systems but show a lack of improvement in residential AHUs which have mostly stayed the same in shape, form, utility and efficiency. These reports highlight some of the emerging technologies that could be used in future air handlers. BTO is seeking new technologies like those highlighted in the BTO reports that can radically enable a transformative change in the design, manufacturability, maintenance/service, performance, and energy savings from these next generation residential AHUs.

Today's residential air handlers used in central air conditioners and heat pumps systems typically look like large rectangular metal box and have for several decades. These air handlers physically connect to a home's ventilation system that distributes the conditioned air through the home with the responsibility of delivering comfort to its residents. These units are manufactured at a factory and final installation is done onsite by joining these components together and mating them to a building's duct system. Most residential air handlers include several major components including a blower (with an electric motor), an evaporator/condenser coil (heat exchanger) if a heat pump system, a furnace section if using natural gas to heat a home, and an evaporator coil for cooling if it is also an air conditioning system. Today these major components are optimized as independent components. A transformative change in air handler design will require that these components instead be optimized as a system.

BTO is seeking to develop the next generation of air handlers that are more than just better motor designs, but also new system configuration based on advanced computational fluid dynamics (CFD) modelling that addresses the problem holistically (e.g. relationship of fans with other subcomponents, etc.), and enables the next generation of air handlers and of residential HVAC technology overall. The focus is on innovative solutions that can reduce the energy consumption of an air handler or AHU by a minimum of 25%, enhance the overall performance of the HVAC system greater than 5% (heating and/or cooling modes), and enable potential new system configurations and heat exchanger designs. These designs and solutions also include natural gas or fuel-fired solutions.

Most of these system's energy efficiency measures utilize a seasonal energy efficiency ratio (SEER in British thermal units per Watt-hour (Btu/Wh)), and the heating seasonal performance factor (HSPF in British thermal units per Watt-hour (Btu/W-h)). For this solicitation, these metrics should be used to justify all system energy efficiency claims. Given the wide range of units and sizes in the field, the applicant is required to pick a representative unit as the baseline state-of-the-art (SOA) unit and make all efficiency and performance claims based on that representative unit. Please justify the SOA unit and why it makes sense for your claims and the rationale behind its choice. While proposals are sought that focuses on residential air handlers, it is expected that some of these innovations could potential impact commercial AHUs as well. Applicants should capture these benefits and others if relevant.

Applications should report out the expected costs of the proposed system configuration, providing analysis to support all claims made. Applications must clearly state how the following targets will be met:

Next Generation Residential Air Handlers Targets	
Energy Efficiency	> 25% decrease in the energy consumption of an air handler or AHU and enhance the overall energy efficiency performance of the HVAC system > 5% (heating and/or cooling modes)
Physical size	< 10% greater than 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, should improve system reliability
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
First Cost, system	No increase as compared to state-of-the-art system designs

Questions – Contact: Antonio Bouza, antonio.bouza@ee.doe.gov

b. Novel Materials and Processes for Solid-State Lighting

There are numerous fundamental advancements of materials and process that are applicable to energy saving technologies of interest to the DOE that address high priority research needs such as energy storage, critical materials usage, efficient manufacturing, etc. Within EERE's Building Technologies Office (BTO), there are few other opportunities capable of achieving the remarkable energy saving potential promised by solid-state lighting (SSL) [1]. Today, SSL has begun to transform the general illumination landscape in a very significant and energy efficient manner, it is believed that only about 10% of the total energy conserving potential of SSL has been realized using currently available technologies. To achieve the goal of reducing domestic energy consumption of general illumination 50% or more through SSL, many innovative and technology breakthroughs are required in manufacturing processes, control systems, device architectures and constituent materials that are the subject focus of this subtopic [2]. Due to the tremendous breadth of the materials advancements required throughout the SSL landscape, this broad subtopic is described in three more narrow categories of novel materials needs or areas of interest. Only proposals that address these specific materials-related opportunities will be considered here.

Inorganic Light Emitting Diode (LED) Materials:
Considerable research and materials development have been applied towards overcoming the well-known droop in III-Nitride Light-Emitting Diode (LED) efficiency with longer wavelengths particularly in the green and amber wavelength regimes [3]. Often referred to as the “Green-Gap”, BTO has systematically advanced the basic understanding of the fundamental mechanisms that dictate efficiency and droop by sponsoring early-stage research in this area over the past decade. The result has been a more comprehensive scientific understanding of the fundamental mechanisms but there remains a need for early-stage R&D to distill this knowledge to advance new and novel emitter materials and the processes used to efficiently and cost effectively manufacture them with reduced droop performance and spectral characteristics suited for general lighting applications.

Another area that has received investment by BTO is high-efficiency wavelength conversion materials and processes commonly referred to as downconverters. While most materials development has been focused on production of warm-white LEDs using existing Yttrium Aluminum Garnet (YAG)-based phosphors, other promising wavelength conversion materials and process have been developed recently including those that do not depend on critical materials such as Rare Earth Elements. Other examples include nanocrystals [4] and quantum dots [5] made with a variety of constituent materials. While promising, many of these candidate solutions still have challenges with poor thermal stability and non-uniform performance over long lifetimes. They also suffer from and high cost to manufacture or incorporate into device designs that are competitive and compatible with LED architectures that are widely used in high brightness lighting applications today. Thus, there remains a considerable opportunity for government sponsored research in alternative downconversion solutions that meet the quantum yield, thermal stability, spectral performance, color consistency and optical flux saturation requirements with a new and potentially simpler manufacturing process.

Organic Light Emitting Diode Materials:
Organic Light Emitting Diode (OLED) efficiency is limited by many factors that require breakthroughs in constituent materials. Among the most significant materials and manufacturing process related needs are 1) high efficiency yet stable blue emitter materials, 2) high performance electrically conductive layers with superior visible light transmission properties, and 3) device encapsulating or integrated substrate materials. Considerable research has already been completed in each of these areas with varying levels of success [4]. Many of these new and novel materials advancements have been proven in laboratory experiments but have not met the simultaneous requirements of long lifetime, inexpensive manufacture and significant performance advancement. Innovative and novel solutions to this significant materials and process challenges are welcome in this area.

An important example of a novel materials need is conductive materials of advanced composition and design that perform multiple functions such as being highly transparent and electrically conductive. In contemporary OLEDs, efficient operation depends on superior charge introduction into various photonic layers yet whose optical transmission at wavelengths of practical value is simultaneously very high. These contradictory performance requirements are typically satisfied using Transparent Conducting Oxides (TCOs). Indium Tin Oxide (ITO) possessing an In:Sn atomic ratio of about 10:1, is the most common TCO coating used to manufacture OLED anodes in generic bottom-up deposited layer device designs. ITO is not, however, an ideal anode material for high efficiency OLEDs [4]. It has: inappropriate work function, difficulty in creating desired patterns, poor thermal stability, integration and bending on flexible substrates. It also requires high quality Indium and must be processed at high temperatures. All these factors limit the high-speed manufacture of integrated ITO substrates. While considerable research towards identification of alternative materials or structures for OLED anodes has been completed to date [4], there appears to be only limited commercial success. Therefore, in addition to proposed novel and unproven materials solutions to this challenge, advancement of known alternatives or processes are welcome in this area.

Optical Materials for High Efficiency Luminaires:
By their very definition, all high efficiency SSL technologies used in buildings must operate best within the visible portion of the electromagnetic spectrum. This creates special encapsulation or packaging challenges for both LED and OLED designs. At the device or light engine level, new materials and encapsulation methodologies must manage the refraction index to improve light extraction from these devices. New materials or alternative to conventional materials such as silicone composites, glass, or polymers that are both stable and inexpensive are needed. This area includes the development of new and novel optical materials or matrices applicable to either LEDs or OLEDs and may be intended for either internal or external extraction efficiency improvement. Viable candidate approaches may incorporate other constituent materials such as downconverters for example, along with a proposed optical advancement that is novel or innovative.

Luminaires intended for use with SSL sources are typically designed based on their older counterparts that used a legacy lighting technology such as linear or compact fluorescent lamps. This common practice, while being easy and inexpensive to implement, has limited the market penetration of efficient luminaires for a variety of reasons. Arguably, the most significant is the limited availability of inexpensive, lightweight, and easy to manufacture optical materials that manage either the directional distribution of light from an LED or the diffuse light produced from an OLED better than the traditional material used with legacy lamp types. Materials that control light efficiently produced within the luminaire or to create beam profiles that are more easily and efficiently controlled are needed. Novel materials and optical designs that meet these performance challenges at competitive manufacturing costs and complexity are sought under this subtopic. Viable proposals to this subtopic may include integration of other functionality such as variable beam profiles, downconverters, or methods used to manufacture them.

Summary:
Irrespective of the technical approach proposed to meet one or more of the above areas of interest, 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. The primarily benefit of the research proposed under this topic must be aligned with the price and performance goals described in the SSL Research and Development Plan [2].

Questions – Contact: Mary Hubbard, mary.hubbard@ee.doe.gov

c. Automated Point Mapping for Commercial Buildings

One of the major barriers to the implementation of advanced data analytics (e.g., automated fault detection and diagnostics or AFDD) and controls software can be the laborious and expensive process of tagging and mapping individual points that correspond to sensors, actuators, and controllers located throughout a building. This long process limits the affordability of emerging analytics engines or software applications under development for optimizing building energy management, and ultimately, BTO's programmatic energy savings performance goals achieved through innovations in sensor and control technologies [1]. These technologies also form a fundamental backbone for optimizing grid services from buildings in modernizing the grid.

The challenge is especially pronounced for large commercial buildings due to the large number of points involved. Assuming one minute for identifying and commissioning each point, for example, should require 833.3 labor hours for a building consisting of 50,000 points [2]. Retrofit applications become even more complex due to inconsistent, mislabeled, or customized labeling of points associated with previously installed building automation systems (BAS) from different vendors, manufacturers, and installers. Furthermore, standardized point names do not include all metadata or descriptive information about a point (e.g., sensor placement location) necessary for mapping. Manual assignment of semantics or meaning to distinguish points is also time-consuming and subject to error. Standardized protocols (e.g., BACnet [3], LONWorks) to enable communications and automate the detection and identification process, consistent and harmonized naming conventions, semantic data models, and taxonomies or schema (e.g., Project Haystack [4], Building Information Models, Ontologies) are necessary and in development. Limitations exist in terms of completeness, including the ability to capture uncertainty [5, 6]. This is being addressed through techniques to automate the conversion of data from existing buildings [7, 8], as well as the development of a schema that includes an open reference implementation standard for evaluation of its effectiveness [9, 10]. Solutions are also being developed using machine learning to reduce the manual mapping process by automatically inferring names and data through statistical models that exploit patterns or correlations of points [11, 12, 13, 14, 15].

Leveraging these advancements, BTO is specifically interested in the development of innovative, early-stage algorithmic solutions to remaining technical issues for point identification that are not being currently addressed in the approaches described, such as identification of errors in existing/new point names, identification of physical location of points, and any other issues not mentioned above. These solutions should leverage and complement industry-driven protocols, as well as taxonomies and schema under development to the best extent possible. Algorithms developed in Phase I should include proof of concept validation that can be transitioned into a field testing and validation in Phase II that can inform development of commercialized product through follow-on private sector investment.

Questions – Contact: Marina Sofos, marina.sofos@ee.doe.gov

d. R&D to Augment Building Energy Modeling

BTO is seeking proposals for methods and tools that complement whole-building energy modeling and leverages it, its inputs, outputs or both to drive complementary analyses or vice versa. Whole-building energy modeling is just one method for informing building energy efficiency projects. Others include life-cycle analysis, daylighting, indoor and outdoor environmental quality and thermal comfort, urban microclimate, cost, water use, resiliency, and others. These models often leverage data that is available for

– or produced by – whole-building energy analysis. Some can, in turn, inform or enhance whole-building energy modeling.

The expected output of a successful Phase I project is a proof of concept of a new or enhanced modeling capability that is relevant to building projects. Applicants are encouraged to identify a small group of relevant partners to help provide feedback and demonstrate the utility and relevance of the modeling. Successful Phase I projects should be ready to apply for Phase II awards that enable validation of the modeling approaches developed in Phase I.

Proposals may use open-source BTO-funded tools such as EnergyPlus and OpenStudio, but are not required to do so. Proposals may also leverage BTO-funded data repositories such as the Building Performance Database (BPD) and the Standard Energy Efficiency Platform (SEED), but are not required to do so. Where applicable, proposals are encouraged to use open data exchange schema such as BuildingSync, HPXML, and CityGML.

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

e. Data Fusion for Building Technology Projects

BTO is seeking proposals that use new and emerging data fusion and data science techniques to advance the state of the art for data-driven building technology projects at either the individual building or building stock scale. In addition to energy-efficiency, proposals may also address areas that are of more recent interest to BTO, including demand reduction and flexibility, critical water issues, and resiliency.

The expected output of a successful Phase I project is a proof of concept of new and emerging data science techniques which are relevant to building technology research projects. Successful Phase I projects should be ready to apply for Phase II awards that will focus on the testing and validation of the data science approaches developed in Phase I.

Data standardization is one of many barriers to the effective testing and validation of advanced building technologies. Lack of standardization makes it difficult to aggregate multiple data-sets that provide similar information about different sets of buildings into a single larger set that can support more robust analysis. More significantly, it prevents "fusion" of data-sets that provide different information about the same set of buildings to enable more advanced research. Relevant standards and schema include the Unique Building Identifier (UBID), the BEDES data dictionary, CityGML, EnergyADE, GreenButton, BuildingSync, and Home Performance XML. Software infrastructure includes the Building Performance Database (BPD), the Standard Energy Efficiency Data (SEED), and the Audit Template.

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

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10. FUEL CELLS

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

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

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

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

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

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

a. Fuel Cell Membranes and Ionomers

Polymer electrolyte membrane (PEM) fuel cells are a leading candidate to power zero emission vehicles, with several major automakers already in the early stages of commercializing fuel cell vehicles powered by PEM fuel cells. PEM fuel cells are also of interest for stationary power applications, including primary power, backup power, and combined heat and power. Commercial PEM technology typically is based on perfluorosulfonic acid (PFSA) ionomers, but these ionomer materials are expensive, particularly at the low volumes that will be needed for initial commercialization. Non-PFSA PEMs, including those based on hydrocarbon membranes, represent a lower-cost alternative, but government sponsored R&D is needed to improve non-PFSA's relatively low performance and durability.

Development of novel hydrocarbon and other ionomers, including non-PFSA PEMs suitable for application in fuel cells is solicited through this subtopic. Novel PEMs developed through this subtopic should have all properties and characteristics required for application in PEM fuel cells for transportation applications, including:

- High proton conductivity in a range of temperature and humidity conditions;
- Good film forming properties enabling formation of thin (<10 µm) uniform membranes;
- Low swelling and low solubility in liquid water;
- Low creep under a range of stress, temperature, and humidity conditions;
- Low permeability to gases including H2, O2, and N2;
- Chemical and mechanical durability sufficient to pass the accelerated stress tests.

The goal of any proposed work under this subtopic should be to produce a PEM using an affordable and durable ionomer that can meet or exceed all of the 2020 technical targets simultaneously in the table below. PEM technology proposed for this subtopic should be based on non-PFSA ionomers, but may include reinforcements or other additives.

Membrane samples should be tested at an independent laboratory at the end of each phase. Phase I should include measurement of chemical and physical properties to demonstrate feasibility of concurrently meeting or exceeding the targets below related to these parameters, while Phase II should address long term durability and development of manufacturing processes to meet the cost targets.

Technical Targets: Fuel Cell Membranes for Transportation Applications Excerpted from [1]

Characteristic	Units	2020 Targets
Maximum oxygen crossover	mA / cm2	2
Maximum hydrogen crossover	mA / cm2	2
Area specific proton resistance at:		
Maximum operating temperature and water partial pressures from 40–80 kPa	Ohm cm2	0.02
80°C and water partial pressures from 25–45 kPa	Ohm cm2	0.02
30°C and water partial pressures up to 4 kPa	Ohm cm2	0.03
-20°C	Ohm cm2	0.2
Maximum operating temperature	°C	120
Minimum electrical resistance	Ohm cm2	1,000
Cost	$ / m2	20
Durability		
Mechanical	Cycles until >15 mA/cm2 H2 crossover	20,000

Chemical	Hours until >15 mA/cm2 crossover or >20% loss in OCV	>500
Combined chemical/mechanical	Cycles until >15 mA/cm2 crossover or >20% loss in OCV	20,000

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

b. Nozzles for High-Pressure, Low-Temperature Gas Fills

The cost and reliability of nozzles for dispensing of hydrogen into light duty fuel cell vehicles is currently a critical barrier to the viability of hydrogen infrastructure. Hydrogen dispensers currently account for 35% of unscheduled maintenance events at stations, and design flaws are one of the most common causes of nozzles losing functionality [1]. Innovations in manufacturing techniques for nozzles could reduce their capital costs, improve the reliability of fueling stations, reduce leakage of hydrogen, and ensure domestic leadership in the emerging area of hydrogen infrastructure. Domestic stakeholders in related industries, such as suppliers of compressed natural gas (CNG) components, may be particularly well-positioned to leverage existing technologies in R&D on hydrogen fueling.

Proposals are sought for the development of hydrogen fueling nozzles for use at high-throughput stations (80% utilization) for light-duty vehicles, using filling methods compliant with the Society of Automotive Engineers (SAE) J2601 fueling protocol [2]. Nozzles should be capable of incorporating station-to-vehicle communications technologies that are currently in use (e.g. infrared communication between the vehicle and the fueling station), or being considered for use in future stations (e.g. wireless communication). Phase I of the proposed work may include evaluation of advanced materials, manufacturing techniques (e.g. additive manufacturing), or designs for nozzles, along with down-selection of one concept for further evaluation. Phase II may include development of a nozzle prototype, experimental verification of prototype performance, and techno-economic analysis of nozzle cost. Nozzle concepts proposed must target: 1) hydrogen fills per flow rates, temperatures, and pressures specified in the SAE J2061 protocol, 2) a service life of at least 25,550 fills/year for 10 years, and 3) a capital cost of $7,000 or less for nozzles, not including the cost of communications components.

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

c. Active Low Cost Thin Film Hydrogen Sensors

Hydrogen gas is used in a variety of sectors today (e.g. oil refining, coal power plants, fueling stations for fuel cell vehicles), and safe operation requires the ability to rapidly detect and contain leaks. Approaches currently used for leak detection include monitoring of drops in pressure, along with use of thin films with chemical indicators that change color in the presence of hydrogen. While current technologies can detect leaks from point sources (e.g. due to fittings or failure of seals), most cannot also autonomously communicate, in rapid dynamic response times, with a facility to notify its operator of the leak. Additionally, their performance is challenged in outdoor environments, where heightened sensitivity is required due to the potential for hydrogen to diffuse widely.

This subtopic seeks R&D on enabling viable leak detection technologies including integration with communications technologies that notify a system operator when a leak occurs. Phase I funding is for proof-of-concept R&D and testing of communications concepts (e.g. radio frequency identification distributed networks) that may be integrated with existing leak detectors. Phase II funding would enhance the sensitivity of the leak detection technologies to improve their performance in outdoor environments while meeting affordability targets. Concepts proposed should be resilient when exposed to high concentrations of hydrogen, compatible with a large assortment of operating systems, and capable of communication with a facility within sub seconds.

Questions – Contact: Laura Hill, Laura.hill@ee.doe.gov

d. Smart Sensors for Structural Health Monitoring (SHM) of Composite Overwrapped Pressure Vessels (COPVs) of On-board Hydrogen Storage for Fuel Cell Electric Vehicles (FCEVs)

Fuel Cell Electric Vehicles (FCEVs) are now commercially available in certain parts of the U.S. and around the world with many meeting the initial DOE goal of a 300 mile driving range using carbon fiber composite overwrapped pressure vessels (COPV) rated for 700 bar compressed hydrogen service. [1] In addition, there are now approximately 35 retail hydrogen refueling stations open to the public in California with several more expected to come online soon. [2]

To harness American energy resources safely and efficiently and to improve the safety of the high-pressure COPVs, there is interest in developing health monitoring sensors that can provide real-time indication of potential damage or degradation of the composite overwraps. Real-time sensors could also eventually lead to reduction in the manufacturing overdesign of the COPVs and thus lower overall cost. Damage to the composite overwraps can result from pressure loads over time, environmental induced degradation in operation, and accidental mechanical impacts. COPVs can be subjected to a broad range of damage mechanisms, either usual (e.g., cycling) or accidental (e.g., car accident, fall or impact during transport, handling, installation, etc.). Potential damage mechanisms can include fiber breakage, delamination and matrix cracking. R&D is needed to improve characterization of COPV damage resulting from a mechanical impact (e.g. from a projectile or drop), its evolution under typical in-service loadings (monotonic pressurization, filling/emptying cycles, etc.), and the corresponding loss of performance. This is partially due to there being only a few studies addressing the consequence of impact on the residual lifetime of composite materials obtained by filament winding. In addition a surface impact could create damage in the thickness of the composite and can even damage the liner. [3] Such sensors could also be utilized for COPVs used in other applications, such as onboard compressed natural gas (CNG) vehicles and self-contained breathing apparatuses (SCBA) used by first responders.

To ensure of the structural health of the COPVs to prevent unexpected failure, online monitoring of the tank would be of value. Applications are sought to perform early stage research, development and demonstration (RD&D) of techniques/instruments/technologies that can monitor vital aspect of COPVs. The monitoring needs to be imbedded/integrated into the COPV and can monitor COPV features passive or actively.

Some potential areas of interests include, but are not limited to:

- Non-Destructive Evaluation (NDE) techniques for continuously monitoring structural health for improved fatigue life, stress rupture, and damage tolerance.
- Gauges for sensing and recording/reporting abnormalities in stress, strain, localized pressure and temperature rise, cycle counting, and scheduled maintenance.
- Sensors for detecting permeation, leakage, pressure decay, humidity, and localized heat transfer.
- Massive data collection effort through network connected SHM sensors to drive reduction in statutory overdesign (e.g. reduce safety factor and/or necessary manufacturing overdesign).

Questions – Contact: Bahman Habibzadeh, bahman.habibzadeh@ee.doe.gov

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e. Innovative Concepts for Hydrogen Conversion to Liquid Hydrocarbon Fuels

Applications are sought for innovative catalyst and reactor designs for synthesis of liquid hydrocarbons from captured CO2 and hydrogen produced from renewable energy sources.

One promising pathway for utilization of stranded renewable energy resources is synthesis of renewable liquid hydrocarbon fuels from captured CO2 and H2 produced through water splitting utilizing renewable energy. These liquid hydrocarbons are compatible with the existing fuel infrastructure and can provide means for inexpensive transportation, storage, and distribution of renewable energy, ultimately creating a sustainable carbon cycle for energy production and utilization.

Several commercial processes can produce liquid hydrocarbons from coal or natural gas, (e.g. Fischer-Tropsch, Methanol, DME synthesis) by first converting the fuel into syngas (a mixture of CO and H2) followed by liquid hydrocarbon synthesis step. Presently, these processes are generally carried out in large scale reactors under continuous operating conditions. Several important modifications to the existing processes will need to be implemented in order to make them compatible with liquid hydrocarbon production from captured CO2 and renewable H2 and adapted to utilizing renewable energy sources.

Firstly, the processes and catalysts have to be modified to operate with CO2 instead of CO in the feed. Conversion of CO2 into CO in a reverse Water-Gas-Shift (RWGS) process is one option. Direct synthesis from CO2 and H2 is another, more direct approach. Secondly, the hydrocarbon synthesis processes have to be adapted to operation with inherently intermittent and distributed renewable energy sources, such as wind or solar. This will require operating smaller production units that are capable of frequent start/stop and production ramping up and down [1, 2, 3].

Questions – Contact: Eric Miller, eric.miller@ee.doe.gov

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11. GEOTHERMAL

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

Geothermal energy is secure, reliable, flexible, and constant. It continues to be one of America's best choices for low-cost renewable energy in power generation and in direct-use applications for heating and cooling of American homes and businesses. The Geothermal Technologies Office (GTO) focuses on applied research, development, and innovations that will improve the competitiveness of geothermal energy and support the continued expansion of the geothermal industry across the US [1]. Currently, the U.S. has 3.8 gigawatts electric (GWe) of installed geothermal capacity, while advances in technologies such as Enhanced Geothermal Systems (EGS) could enable access and deployment of more than 100 GWe of new geothermal capacity. Consistent with the administration's R&D priority in American Energy Dominance, this topic seeks to invest in early-stage, innovative technologies that show promise in harnessing new domestic geothermal resources that provide clean, affordable, and reliable energy. Because deploying additional baseload geothermal energy will contribute to grid reliability and resilience as well as national security, this topic supports the Acting Assistant Secretary for EERE's grid integration priority.

A Phase I application should focus on proof of concept and bench scale testing that are scalable to a subsequent Phase II prototype development. Applications must be responsive to the following subtopic. 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.

Grant applications are sought in the following subtopic:

a. Improved Downhole Telemetry for Geothermal Drilling

In this topic, GTO solicits innovative research and development projects to enable improved downhole telemetry for geothermal drilling operations. Drilling operations can be up to 50% of the cost of the development for a geothermal project [2]. Improving downhole telemetry during drilling can reducing drilling costs and risks that would help spur the geothermal industry to expand capacity in the near-term. The International Association of Drilling Contractors defines downhole telemetry as “Signals transmitted in real-time (while drilling) from an instrument located near the bottom of the drill string to a receiving monitor on the surface (a surface-readout)” [3]. Enabling real-time data transfer from tools and sensors in the bottom-hole assembly (BHA) to the drill operator can lead to improved rates of penetration (ROP), reduced non-drilling time (NDT), and increased safety through real-time wellbore stability monitoring. Additionally, a better understanding of well depth and location and increased control for directional drilling could lead to reduced operational and stimulation costs. Current practices for downhole telemetry include wireline embedded within the drill-pipe, electromagnetic (EM) signals passed through the formation, acoustic signals carried over the drill-pipe, and sonic signals carried the drilling fluid or “mud pulse.” Of these options, wireline telemetry is often not feasible and mud pulse, acoustic, and EM have limitations on bit transmission rates and data quality [4]. Additionally, geothermal wells can be drilled without a drilling fluid (called “air drilling”), which eliminates the option of mud pulse telemetry. This topic is seeking innovations that go beyond these current practices seeking to improving bit transmission rate, reducing signal attenuation, and/or reducing costs by at least 25% over current state-of-the-art. Responses to this topic must address downhole telemetry issues specific to geothermal drilling, which can include, but are not limited to: higher temperatures (>250°C), drilling through crystalline formations with little to no porosity, and air drilling.

While the high temperatures in geothermal wells often cause issues with standard electronics associated with downhole telemetry, this topic is not seeking innovations solely into new high-temperature electronics. Novel wide-bandgap semiconductors may only be proposed as a component to an otherwise innovative downhole telemetry system, not as the proposed innovation.

This topic is solely focused on downhole telemetry during geothermal drilling operations; innovation into other types of telemetry (such as long term well monitoring, fiber optic cables embedded in wellbores, etc.) will be deemed not responsive.

Questions – Contact: Joshua Mengers, joshua.mengers@ee.doe.gov

References:

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

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12. SOLAR

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

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

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

Within this Funding Opportunity Announcement, SETO is releasing this Topic and joining the EERE Advanced Manufacturing Office in releasing Joint Topic 10 on "Innovation in solar module manufacturing processes and technologies."

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

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

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

a. TECHNOLOGY TRANSFER OPPORTUNITY: Real-Time Series Resistance Monitoring in Photovoltaic Systems

Sun Open Circuit Voltage (Suns-Voc) analysis provides a method to probe the hypothetical, series-resistance free, current-voltage (I-V) curve of a photovoltaic device. While historically Suns-Voc has been used for the analysis of photovoltaic cells under controlled laboratory conditions, recent work at NREL has extended the Suns-Voc methodology to develop automated Real-Time Series Resistance ("RTSR") monitoring capabilities for photovoltaic modules in the field. NREL's RTSR methodology is useful to passively detect common failure modes found in installed modules, including broken ribbons, failed solder bonds, or improperly joined junction/combiner box connections in modules and systems all under normal outdoor operation, by analysis of current and voltage information taken from the inverter. Early detection of these failure modes is critical for solar O&M providers in order to reduce potential fire risk, as well as to identify degraded, improperly installed, or otherwise underperforming modules in need of replacement. NREL is currently looking for partners to develop hardware and software related to the improved Suns-Voc techniques for commercial applications.

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: U.S. Patent Application Serial No. 15/564,357
Publication date:
Filing date:
http://appft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&p=1&u=/netahtml/PTO/srchnum.html&r=1&f=G&l=50&s1=20180131322.PGNR.

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

b. TECHNOLOGY TRANSFER OPPORTUNITY: PV Module Soiling Spectral Deposition Detector

Accumulation of dust, particles, and dirt on the surface of photovoltaic modules can cause a reduction in the intensity of light transmitted through the module cover and therefore in the amount of energy generated. Recent studies have shown that total power losses in Europe and the U.S. approach 7% annually due to soiling and are much worse (up to 70%) in other parts of the world. This has significant impact on the solar market; a flat 4% soiling loss affecting all PV capacity worldwide has been estimated to result in potentially over $1 Billion in lost revenue annually. While PV modules can be cleaned, the one-time cost for doing so is quite expensive: between $0.20-0.50 per module (or $5,000 for a 10 MW system).

Thus, it is important to monitor soiling in order to plan for the most accurate cleaning schedule of a system; while uncleaned modules result in unnecessary revenue loss due to diminished energy generation, the cost of cleaning modules can be prohibitively expensive if ineffectively performed. There exists a need to determine the exact level of soiling present in an installed PV system so as to make educated decisions about when cleaning of the system is required. NREL has developed a prototype device which can detect the amount of soiling present throughout an installed PV system and correlate that soiling level with lost power generation. In this way, informed decisions about how and when to clean installed modules can be made. NREL is currently looking for a partner to perform continued field-tests and optimization of the device in various real-world scenarios, environments, and weather conditions.

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: U.S. Patent Application Serial Nos. 62/652,955 & 62/690,086
Publication date:
Filing date:

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

c. Storage Technologies to Enable Low-Cost Dispatchable Solar Photovoltaic Generation

One of the priorities of the SETO office is to support early-stage, innovative solar technologies that show promise in harnessing American energy resources safely and efficiently. In this topic, we are interested in exploring approaches that can provide opportunities for energy storage that is well suited to integration with solar photovoltaic technology or optimizing energy use. SETO plans include collaboration with the U.S. Department of Energy's Office of Electricity [1] to select and manage awards under this subtopic.

As solar electricity costs continue to decrease, the percentage of solar photovoltaic generation (both from distributed and utility-scale systems) in the US increases. This opens up new challenges and opportunities for the development of novel technologies that can enable low-cost dispatchable solar PV generation that enables increased integration and operation flexibility and allow solar electricity to be better matched to demand.

In this subtopic, SETO is seeking innovative storage technologies that could be co-located with solar photovoltaic systems and are fully compatible with the characteristics of the typical output of a solar inverter (medium-low voltage, variable generation). Technologies proposed should leverage attributes specific to solar photovoltaic generation technologies while addressing current integration gaps and challenges. SETO is especially interested in novel thermal, mechanical or chemical storage technologies that can demonstrate clear non-incremental differentiation from the current state of the art.

Applications must include a basic cost-model analysis showing a path to be cost-competitive with current state of the art, and with the potential to increase the utilization of solar photovoltaic generation in the grid. Storage functionalities at any time scale will be considered (minutes, hours, days, seasonal). The application should clearly discuss which energy value stream this technology will target, if successful.

Applications will be considered non-responsive and declined without external merit review if they describe a software-only solution or a solution based on existing battery technologies or if the technology is aimed at self-consumption optimization or the application does not demonstrate a clear innovation compared to current the state of the art.

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

d. Hardened Solar System Design and Operation for Recovery from Extreme Events

One of the priorities of the SETO office is to enhance the ability of solar energy technologies to contribute to grid reliability and resilience as well as national security, including but not limited to security and resilience of the Nation and its critical infrastructure.

Infrastructure systems, including the electrical grid and solar generation assets (both photovoltaic and concentrating solar power) are vulnerable to extreme weather and other disruptive events. Increased asset resilience presents opportunities to maximize operability, energy availability (along with communications, water, etc.), and to minimize restoration costs following these occurrences.

In this subtopic, SETO is seeking innovative proposals to improve the ability of solar assets and systems to quickly recover in response to extreme events. Proposals may address specific component or system designs that passively (such as more structurally robust designs or configurations) or actively (such as array/tracker stow strategies or "hardened" components) improve survival and/or recovery time and minimize cost associated with extreme events.

Applications must include a basic cost-model analysis showing the cost/benefit of the proposed solution in comparison to current state of the art. Applications should also identify a possible case use by defining the time to recover the system fully functionalities, and provide substantiated estimates for the capabilities of the proposed approach.

Targets and metrics for hardened solar system performance could include (but are not limited to):

- Percent of system operable after extreme event (applications should specify type and intensity);
- Survivability at extreme wind loads (> 125 mph) is of particular interest;
- Time to full system operability after extreme event (restoration time);
- Reduction in system restoration cost following extreme event;
- Level of functionality without grid support following extreme event (islanding).

Applications will be considered non-responsive and declined without external merit review if the application does not demonstrate clear innovation compared to current the state of the art, particularly in regard to microgrid and/or islanding behaviors.

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

e. Rural Solar

One of the goals of the SBIR/STTR programs is to encourage the participation of socially and economically disadvantaged persons in technology innovation with increasing geographic diversity of grant funding.

Small and medium-scale (non-utility) solar systems are mostly deployed in urban residential or commercial and industrial settings (we will refer to them as traditional locations within this subtopic). In this subtopic, SETO is seeking the development of solar photovoltaic products or system designs to enable and increase use of non-traditional installation locations when deploying small and medium-scale solar photovoltaic technologies. Such technological solutions could enable rural or economically challenged home or business owners, as well as small land holders to participate in the American solar economy and receive the associated benefits [1]. Proposed solutions should provide particular attention to safety. In addition, solutions should be designed for flexible deployment on a variety of terrains or building types. SETO is particularly interested in technology innovation that would enable installation of solar systems on agricultural or multiuse land, including solutions that allow for complementary land use/value streams in a synergistic manner.

Applications should always identify possible use-case(s) and provide substantiated estimates for the capabilities of their proposed system or technology. In addition, the Applications should demonstrate that the proposed technology is cost competitive (compared to other sources of electricity) in these non-traditional locations. In their commercialization plans, Applicants should include their strategy to enter new and potentially difficult markets outside of the areas that have seen significant solar deployments over the past 10 years.

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

- Undifferentiated products, incremental advances or duplicative products;
- Applications focusing exclusively on HVAC or water heating applications;
- Products or solutions for systems which do not tie to the electric grid (i.e. wholly off-grid applications, portable power, solar fuel);
- Software-only solutions.

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

f. Affordability, Reliability, and Performance of Solar Technologies on the Grid

Fueling America's energy portfolio requires access to domestic sources of clean, affordable, and reliable energy. Unleashing these abundant energy resources will require investment in next-generation energy technologies to efficiently convert them into useful energy services.

In 2017, solar power generated almost 1.5% of the total annual electricity supply in the United States, and the Energy Information Administration projects that solar will grow to 5% of US electricity by 2030 [1]. Further, if the price of solar electricity and/or energy storage declines more rapidly than projected, that percentage could be even higher. But solar is more than just a source of affordable electricity; it also provides the potential to improve grid reliability and resilience, increase employment, create business opportunities, increase energy diversity, expand domestic manufacturing, and provide environmental benefits.

In this subtopic, SETO is seeking integrated solutions that can advance solar energy technologies by lowering cost [2] while facilitating the secure integration into the nation's energy grid. Applications should fall within one of these areas:
Advanced Solar Systems Integration Technologies: responsive applications would advance the prediction, monitoring, and control of solar power production and distribution and the capabilities of solar power electronics;
Concentrating Solar Thermal Power technologies: responsive applications would develop technologies that focus sunlight to generate and store high-temperature heat for electricity generation and other end uses;

Photovoltaic technologies: responsive applications would improve photovoltaic system reliability, annual energy yield, reduce supply-chain capital expense, demonstrate performance of novel photovoltaic materials and components, and develop new photovoltaic materials.

SETO is particularly interested in applications developing:

- Technologies which can reduce the manufacturing costs of solar energy system components or sub-components to boost domestic energy manufacturing and increase U.S. manufacturing competiveness;
- Technologies which enhance the ability of solar energy systems to contribute to grid reliability, resiliency and security;
- Development and publication of replicable system designs for configurations that could be installed across comparable sites (e.g. homes or commercial buildings with similar roofing)
- Designs for photovoltaic modules and system configurations that anticipate updates in codes or safety requirements;
- Technologies to improve recyclability of photovoltaic materials and components;
- Technologies / solutions that reduce the balance of system component of the cost of a photovoltaic system.

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

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

- Applications for proposed technologies that are not based on sound scientific principles (e.g., violates the laws of thermodynamics);
- Applications that fall in any of the other subtopics listed in this funding opportunity announcement;
- Business plans or proofs-of-concept that do not include documentation supporting the necessity or benefit of the plan or concept. Competitive approaches in this application segment should be clearly defined in the application;
- Undifferentiated products, incremental advances or duplicative products;
- Projects lacking substantial impact from federal funds. This subtopic intends to fund projects where federal funds will provide a clear and measurable impact, (e.g. retiring risk sufficiently for follow-on investment or catalyzing development.) Projects that have sufficient monies and resources to be executed regardless of federal funds are not of interest;
- Applications focusing exclusively on HVAC or water heating applications;
- Products or solutions for systems which do not tie to the electric grid (i.e. wholly off-grid applications, portable power, solar fuel);
- Software to facilitate system design or system monitoring;
- Any software solution to improve customer acquisition processes.

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

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

References:

1. Solar Energy Technologies Office, U. S. Department of Energy. https://energy.gov/solar-office

2. Energy Department Announces Achievement of SunShot Goal, New Focus for the Solar Energy Office, U. S. Department of Energy. https://www.energy.gov/articles/energy-department-announces-achievement-sunshot-goal-new-focus-solar-energy-office

3. Solar Energy Technologies Office, Goals of the Solar Energy Technologies Office, U. S. Department of Energy. https://www.energy.gov/eere/solar/goals-solar-energy-technologies-office

References: Subtopic c:

1. Office of Electricity, U. S. Department of Energy. https://www.energy.gov/oe/office-electricity

References: Subtopic e:

1. Cooperative Solar: Driven by Cooperative Principles, NRECA. https://www.cooperative.com/content/public/maps/esri-solar-story-map/index.html

References: Subtopic f:

1. U. S. Energy Information Administration, 2017, International Energy Outlook 2017, U.S. Department of Energy, DOE/EIA-0484 (2017). https://www.eia.gov/outlooks/ieo/pdf/0484(2017).pdf

2. Cole, W., Frew, B., Gagnon, P., Richards, J., et al, 2017, SunShot 2030 for Photovoltaics (PV): Envisioning a Low-cost PV Future, National Renewable Energy Laboratory, p. 69. https://www.nrel.gov/docs/fy17osti/68105.pdf

13. VEHICLES

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

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

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

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

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

Grant applications are sought in the following subtopics:

a. Electric Drive Vehicle Batteries

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

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

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

b. SiC Devices Suitable for Electric Vehicle Extreme Fast Chargers

The push to reduce charging time through Extreme Fast Charging (XFCs) for Battery Electric Vehicles (BEVs) creates a suite of intertwined R&D challenges. In addition to the R&D challenges for vehicles and battery technologies, there is a distinct need to understand how fast charging up to 400 kW will impact Electric Vehicle Service Equipment (EVSE) and XFC-related infrastructure costs. Design of these charging stations needs to include power electronics that can withstand elevated current and voltage levels for vehicle charging. Performance requirements and gaps for XFCs can be found at: https://www.energy.gov/sites/prod/files/2017/10/f38/XFC%20Technology%20Gap%20Assessment%20Report_FINAL_10202017.pdf [1].

The planned voltage and current levels for XFC, require high power semiconductors to achieve high power levels and short recharge times. A medium voltage grid input can reduce installation costs and increase efficiency for vehicle charging using solid state approaches to grid isolation and power conditioning, and can contribute to grid reliability and resilience as well as national security. In particular, high voltage Silicon Carbide (SiC) devices with their inherently high breakdown voltage and low loss characteristics are suited to fast charging applications. This subtopic seeks proposals to develop devices with high current and voltage ratings that will enable improvements in vehicle extreme fast chargers.

This subtopic seeks proposals that overcome the limitations of currently available technologies by demonstrating the successful production of > 150A, > 1200V rated SiC devices that are suitable for extended use in high power EVSEs. Specifically, prototypes produced in Phase II should pass full or partial qualification specifications or standards at high device production yields. In Phase I, device production quantities are not expected to be sufficient to pass full qualification. In Phase I, applicants should show a relationship to, and demonstrate an understanding of, electric vehicle charging application requirements and environments. Examples include fast charging requirements for surface and/or substrate treatments and processing, compatibility with existing power module, or power stage packaging and processing. Other requirements are related to design for long-term reliability even with device degradation. Proposals should show a path towards full qualification of XFS technologies with commercial-ready devices integrated into a functional module by the end of Phase II.

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

c. Reduction of Thermal and Friction Losses in Internal Combustion Engines

Applications are sought to develop technologies that can provide significant fuel efficiency gains to reciprocating internal combustion engines without appreciable increases in cost or complexity. Potentially effective approaches for increasing efficiency include improved thermal management strategies, such as use of thermal barrier coatings or efficient, low-cost waste heat recovery strategies, and friction reduction strategies, such as use of low friction coatings or surfaces. Refer to the Advanced Combustion and Emission Control Roadmap here:
https://www.energy.gov/sites/prod/files/2018/03/f49/ACEC_TT_Roadmap_2018.pdf [1].

Applications must demonstrate that the target technologies:

- Are viable in current reciprocating engine architectures;
- Are compatible with widely available fuels and lubricants;
- Have a low expected additional cost to implement on an automotive or heavy-duty engine;
- Work reliably for the typical lifetime of the vehicle;
- Are likely to be successfully implemented on a modern, production automotive engine in Phase II.

Reporting must include fuel consumption test results compared with a second, unmodified, otherwise identical engine. All fuel consumption testing must be conducted according to engine industry norms. Statistically valid fuel economy improvements (95% confidence level) of at least 2.0% are desired.

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

d. Co-Optimization of Fuels and Engines

On-road transportation is likely to remain reliant on liquid fuels for decades, due to the superior energy density and fast refueling times that liquids afford. As a result, although electrification has promise to displace internal combustion engines in some applications, advances in combustion will still have substantial impact on transportation-based energy consumption and emissions [1]. While benefits can be obtained by improving fuel resources or engine designs independently, an even larger impact can be had by optimizing new fuels and engines in conjunction with each other. For example, rather than finding new fuels that can be integrated into existing engines – such as higher ethanol blends in stock gasoline engines, and biodiesel into typical Diesel engines – or making incremental refinement of existing engines using traditional fuels, there is even greater opportunity in developing new engines to harness the unique properties of alternative fuels. As a result, grant applications are sought to develop engine designs that are co-optimized for operation on a non-traditional liquid fuel, including:

- Light-duty engine designs that utilize a multi-mode combination of spark-ignition and compression-ignition of biomass-based liquid fuel blends to optimize engine operation across the entire load map. These engines should be able to demonstrate at least a 10% improvement in fuel economy over baseline spark-ignition-gasoline operation (i.e., comparable engine on AKI 87 gasoline).
- Medium and heavy-duty engine designs that use non-diesel/biodiesel liquid fuels in compression-ignition architectures. At minimum, such approaches should be able to achieve traditional Diesel torque and efficiency, but with a significant reduction in criteria pollutants and carbon impact.
- Non-traditional engine designs (such as opposed piston engines, or similar architecture deviations) that operate on a suitably co-optimized liquid alternative fuel. The benefits for such technologies must be proportional to the level of deviation required from traditional engine production processes.

Applications that heavily rely on fuels/additives that are not currently produced at significant scale should include techno-economic analysis to justify commercial potential.

Questions – Contact: Kevin Stork, kevin.stork@ee.doe.gov

e. Improving the Performance and Reducing the Weight of Cast Components for Vehicle Applications

The Vehicle Technologies Office Materials Technology Program targets 25% glider weight reduction at less than $5/lb-saved by 2030. Materials play a major role in the U. S. DRIVE Partnership by enabling lightweighting of structures and systems to improve fuel economy and by reducing demands on the vehicle powertrain and ancillary systems [1]. To accomplish these goals it is necessary to reduce the weight of all components within the vehicle. Cast metal components, made from cast iron, aluminum alloys, and magnesium alloys represent a significant percentage of the total vehicle weight and will need to be addressed to meet the stated goals. Although weight reductions can be achieved through materials substitution, the performance of cast metal components is often dominated by the imperfections in the casting that result from the casting process.

Applications are sought to develop and improve casting processes that result in a significant reduction in casting imperfection leading to increases in component strength, fatigue life, and allowing redesigns that lead to significant (>20%) reductions in component weight.

Applications should provide baseline data on target casting process, component, component performance, and baseline material composition(s) and properties. Proposals should include a clear description of the imperfections to be addressed and the methodology to be employed to make the proposed improvements.

Applications should show a pathway to commercial high volume production rates necessary for the automotive industry and demonstrate that there is a high likelihood that the cost effectiveness targets of $5/lb-saved can be achieved by 2030.

This topic does not include a new materials development program and applications containing a new materials development program will be considered out of scope.

Questions – Contact: Jerry Gibbs, jerry.gibbs@ee.doe.gov or Sarah Kleinbaum, sarah.kleinbaum@ee.doe.gov

f. Low Cost, Lightweight, and High-Performance Fiber-Reinforced Composites for Vehicle Applications

The Vehicle Technologies Office's Materials Technology Program targets 25% glider weight reduction at less than $5/lb-saved by 2030. Materials play a major role in DOE's U. S. DRIVE Partnership by enabling vehicle lightweighting of structures and systems to improve fuel economy and reduce demands on the vehicle powertrain and ancillary systems. The Materials Technical Team in the U.S. DRIVE updated its roadmap in October 2017[1]. Within this roadmap, the area of carbon fiber composites is one of the four material systems of the most interest to the automotive industry. While the current materials focus of the DRIVE partnership is solely for primary structure applications, there are many secondary structures of vehicle components in the automotive industry, which are also critical and in high demand.

Applications are sought to develop and test new innovative materials ideas including carbon fiber and carbon fiber composites. In addition to research on low cost carbon fiber, applications can include development of alternative fibers (e.g., natural fiber/bio-degradable fiber) and resins (e.g., polymers, bio-degradable polymer, fast curing resin), and their processes or any forms of the fiber-reinforced materials such as (continuous, discontinuous, particulate fibers, or hybrid that can make vehicles lightweight and high performance with affordable cost. Applications can also include development of innovative and cost-effective manufacturing processes, such as low-cost, high-speed manufacturing with net shape. In particular, applications are sought to reduce manufacturing cycle time to less than 3 minutes (ideally for 90 seconds), and develop composite intermediates (e.g. prepregs, injection molding compound, SMC, BMC, long-fiber thermoplastics, non-crimp fabrics, and nonwovens). For such applications the expected outcomes should support the automotive industry in utilizing fiber-reinforced composites in high-volume production.

The process from manufacturing carbon fiber to production of finished components is wasteful; it is estimated that more than 30% of produced carbon fiber ends up as waste at some point in the process. The carbon fiber composites industry differs from other automotive materials supply industries in its lack of an effective recycling solution and recyclability. Applications are also sought to develop viable recyclability technologies that can help reduce carbon fiber or non-carbon fiber composites waste. Applications also are sought for technologies that promote lightweight vehicle reusability.

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

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

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14. WATER

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

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

MHK technologies convert the energy of waves, tides, and river and ocean currents into electricity and have the potential to provide locally sourced, clean, and reliable energy. MHK is a predictable, forecastable resource with a generation profile complimentary to the seasonal or temporal variations of other renewable resources such as onshore wind and solar, which can enhance its contributions to grid resilience and reliability. MHK technologies also have the potential to provide cost-effective energy for numerous existing maritime markets, including non-grid connected or remote coastal areas, ocean-based sensors, monitoring equipment (for civilian, scientific, industrial, and national security functions), and autonomous vehicle recharging at sea, as well as reducing desalination costs by avoiding the step of generating electricity.

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

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

Grant applications are sought in the following subtopics:

a. Microgrid for Improved Resilience in Remote Communities through Utilization of Marine Hydrokinetics and Pumped Storage Hydropower

Applications are sought to prove the concept of microgrids for remote rural communities. Applicants should show how such microgrids enhance the ability of marine hydrokinetics (MHK) technologies to contribute to grid reliability and resilience. Inclusion of MHK should offer the capability to reliably provide base load power in these communities in a resilient manner. The application should demonstrate how MHK is less exposed to extreme weather events than other renewable resources.

In 2017, the National Academy of Sciences found that “There is enormous technical potential to using microgrids to make electric service more resilient. This field of research and application is evolving quickly with new control systems, sensors, and distributed energy sources. This rapid evolution of the frontier of technical capabilities is opening a potentially wide gulf between the technical capabilities of microgrid systems and the real world systems that are operational.” To help bridge this gulf, WPTO is interested in proof of concept research on real world applications of marine renewable energy (MRE) technologies that can operate as a base load power supply for small microgrid systems (100KW-1MW) that provide power to remote communities. The proof of concept research should demonstrate the extent to which the following assertions are true:

- Remote rural communities that are vulnerable to power outages resulting from extreme weather events can benefit from microgrids because they are more resilient power supply systems.
- Microgrids from renewable power sources can reduce energy costs in communities that are dependent on diesel fuel for power.
- Incorporating Marine current energy devices into microgrids can reduce their exposure to extreme weather events compared with other renewable sources.

Phase I awards under this topic will prove the concept for the proposed microgrid based on the following:

- Identification of a specific rural community, with average annual electrical demand 100KW-1MW, that currently relies on diesel generators (DG) as primary power supply, and has nearby current energy (river or tidal) resources available to support microgrid operations;
- Possible inclusion of pumped-storage hydropower (PSH), utilizing either natural or man-made water reservoirs, for energy storage requirements to meet electrical grid requirements;
- Replacement of the DGs, though DGs can be included for back-up power, i.e. the system should be capable of operating with the MHK devices supplying baseload operations without utilization of DGs.
- Inclusion of preliminary designs, including specific inverters, controllers and other major component requirements, and the associated system life cycle cost estimates; and
- Life cycle cost comparisons for proposed system, based on available resources for particular community of interest, to the cost associated with the community's current DG operations, maintenance and fuel.

Phase I should include component level testing required to complete the system design. It should also include testing plans to occur in the specific laboratory environment proposed for phase two. The proposed research should identify and model a system consisting of optimal mix of renewable and other local energy resources as appropriate, as well as storage requirements, to serve the community's energy needs.

In Phase II the researchers would complete design and test the system in a laboratory environment utilizing Hardware in the Loop (HIL) to the greatest extent practical at facility such as NREL's National Wind Technology Center (NWTC) or the University of Alaska, Fairbanks' Power Systems Integration Laboratory at the Alaska Center for Energy and Power (ACEP).

Phase II must also include an evaluation of global potential for microgrids for improved resilience in remote communities with average annual electrical demand 100KW-1MW through utilization of MHK and PSH.

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

b. Ocean Energy Storage Systems

Energy storage is a critical component of renewable energy systems to overcome intermittency. Research on electrochemical storage methods, and integration with renewable energy generation sources, has thus far focused on land-based systems such as solar and wind. Generally these systems are poorly suited for the marine environment and are not optimized for integration with marine energy systems such as wave energy converters or tidal energy turbines. The WPTO has identified numerous non-grid applications that could benefit from marine energy, but nearly all of them require an energy storage component. Examples include charging underwater vehicles at sea, powering ocean research devices, and providing emergency sources of electricity. For a marine energy converter to successfully enter these markets it must have a well-defined and reliable energy storage system.

WPTO seeks to fund research and development on novel ocean energy storage systems that can provide functions similar to electrochemical battery storage and are designed for integration with marine energy systems. Examples could include systems using pneumatic, hydraulic, or thermal energy storage. Ocean energy storage could also include systems that are analogous to compressed air energy storage (CAES) or pumped-hydro storage (PHS), but operate underwater using the weight of the water column to pressurize a fluid or gas. Novel electrochemical storage systems that require ocean water for operation may be considered if marine energy conversion is clearly described as an integral component of the design. The WPTO will consider technologies for various scales and capacities, though the end use application must be clearly identified.

Phase I awards under this topic will carry out early-stage, proof-of-concept research into novel marine energy storage concepts in a laboratory setting. Phase I research should include definition and design of a storage system and sufficient laboratory testing to inform the relative merits of the technology and its potential for scaling-up or commercialization. Phase I laboratory work may include initial research to guide design. It also may include testing of initial components and designs or other necessary steps in early-stage development. In Phase II, the awardee(s) should continue to develop the proposed ocean energy storage system identified in Phase I by building a functioning prototype system and testing it in an intended environment or in a laboratory setting using hardware-in-the-loop testing regime. Phase II awardee(s) must present a clear path for the commercialization of the proposed technology.

Applicants must demonstrate knowledge, experience, and capabilities in developing ocean energy storage systems and include the following in their application:

- The specific end-use application for the storage system; for example, charging underwater vehicles or aerial drones, balancing the grid, or offshore aquaculture farms;
- Required system components, including but not limited to: interconnection, mating, or delivery hardware that allows the storage system to deliver energy to the specified application (e.g. docking station for underwater vehicles or drones), including the power management system and controllers and; other auxiliary systems;
- If applicable, how the system can be charged by marine energy systems such as wave, tidal, or ocean current energy converters;
- The state-of-the-art for incumbent technologies and how the proposed design will overcome existing limitations faced by end-users;
- Capacity rating, rates of charge and discharge, and cycling characteristics of the proposed system;
- Details of work to be performed in Phase I including the design plan, the resources required, and the intended performance targets; and
- Description of Phase II work including the scale of the demonstration prototype, the desired test location or facility, and if possible, end-user partners.

Applicants should also detail how they propose to utilize the grant to advance the state-of-the-art and, if successful, what the commercialization plan is for the energy storage system to be developed under this subtopic.

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

c. Pumping and Compression using Marine and Hydrokinetic Energy

Water pumping is required for many different types of operations, including: a) cooling for manufacturing, and data centers, b) air conditioning, c) power generation, d) seawater desalination, e) irrigation of crops, f) onshore and offshore aquaculture, and g) pumped-storage hydro. Compression is needed for refrigeration or other applications that use gases or compressible liquids as their working fluid.

When these applications are in off-grid areas, the power for pumping or compression is typically provided by diesel generators. MHK may be able to supplant these costly and polluting fossil fuel powered pumps and compressors using the energy contained in oceans and rivers.

MHK pumping has often been considered for desalination systems, in particular wave powered reverse osmosis systems. However, challenges remain in determining how best to integrate MHK technologies. Wave energy converters often act as intermittent positive displacement pumps, delivering seawater at variable flow and non-constant pressures, occasionally resulting in water hammer effects. These pressure fluctuations can be damaging for downstream system components, such as membranes, filters, heat exchangers, or valves. Research addressing these issues is elemental to many different off-grid applications for MHK technologies that require pumping or compression, as well as riverine applications such as freshwater aquaculture or crop irrigation.

WPTO seeks to fund research and development of novel MHK-powered pumping or compression systems to directly pump water or compress gases for off-grid applications. Steady flow, high-head (for pumping systems), high-efficiency designs with minimal maintenance are of particular interest. Research should identify specific end-users or applications for the system and clearly demonstrate how the proposed technology meets customer needs.

Phase I awards under this topic will carry out early-stage, proof-of-concept research into novel MHK pumping or compression systems. Phase I research should involve design of a pumping or compression system and should involve sufficient laboratory testing to inform the relative merits of the technology compared to incumbent technologies and its potential for scaling-up or commercialization. Consideration must be given to the delivery system which will deliver the working fluid to the end-user or application. In Phase II the awardee(s) will continue to develop the proposed MHK pumping or compression system by building a functioning prototype and testing in an intended environment or in a laboratory setting using a hardware-in-the-loop testing regime.

Applicants must demonstrate knowledge, experience, and capabilities in developing MHK pumping systems and include a description of the following in their application:

- The specific end-use application for the pumping or compression system and how it will meet end-user requirements, e.g. to supply adequate water at the required pressure to irrigate a wheat crop in remote communities;
- The MHK resource that will be used to power the system;
- The state-of-the-art for incumbent technologies and how the proposed design will overcome existing limitations, costs, or other pain points faced by end-users;
- The predicted volumetric flow rate, total dynamic head, and other relevant calculated performance characteristics of the intended system as applicable;
- The predicted electrical power or fuel displaced by the proposed design;
- Details of work to be performed in Phase I including the design plan, the resources required, and the intended performance targets; and
- The Phase II work including the scale of the demonstration prototype, the desired test location or facility, and if possible, end-user partners.

Applicants should also detail how they propose to utilize the grant to advance the state-of-the-art, and, if successful, the commercialization plan for the MHK pumping or compression system to be developed under this topic.

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

d. High Value Critical Mineral Extraction from the Ocean Using Marine Energy

The demand for reliable sources of critical minerals is growing, based on likely future scarcities and security concerns for obtaining minerals from international sources that may not be readily accessible to the United States. Most rare earth elements (REEs) and valuable minerals used in the United States are imported from other nations. This reliance on foreign supply constitutes an industrial and national security concern. The development of lower-cost domestic extraction of minerals from the ocean will make these sources more economically attractive and help alleviate international supply concerns. Use of ocean sources of critical materials also will avoid permitting, waste disposal, and public opinion concerns associated with terrestrial mining operations. Of particular importance are those elements for which the United States does not have significant domestic resources or for which there is significant risk of supply disruption. Elements that are considered critical include the REEs (e.g., neodymium, dysprosium, europium, yttrium, and terbium), lithium, tellurium, gallium, and indium.

Seawater contains large amounts of minerals, dissolved gases, and specific organic molecules that can play a role as energy sources or for other industrial uses. Some of the most valuable minerals include the 17 REEs, precious metals, lithium, and uranium. Seawater minerals are generally distributed evenly in seawater. These minerals can be recovered from seawater using adsorption methods that do not require filtering vast amounts of seawater.

Marine Energy could open up unexploited opportunities in seawater mining, which could further expand mineral and gas markets. Seawater mining would also improve the diversity of the U.S. mineral supply chain, eliminating reliance on any one supplier. The availability of marine sources of critical material would provide a price ceiling on the cost of terrestrially obtained critical materials. Extraction of minerals from seawater requires power to operate mechanical adsorbent exposure mechanisms, pump seawater, and operate the electrochemical cell in electrochemical extraction systems.

WPTO seeks applications for developing alternatives to foreign-sourced critical materials using marine energy to address US security, trade gaps, and mineral scarcity. Critical materials include, but are not limited to, rare earth elements.

In Phase I awardees will carry out (1) proof of concept research which includes appropriate lab testing for extracting minerals from sea water using marine energy; (2) a study to understand economics and scales to extract high value minerals commercially; and (3) development of a prototype for testing in Phase II. In Phase II the awardee(s) will build and test a promising mineral extraction technology powered by a small scale marine energy device.

Applicants must also demonstrate knowledge, experience, and capabilities in marine energy capture as well as an understanding of sea water mineral extraction technologies and include the following descriptions in their application:

- The required marine energy generation infrastructure and power requirements;
- Mineral extraction technologies and efficiencies being considered;
- Concepts on platforms for concentrated mineral solute transfer or similar materials transfer;
- The US mineral trade gaps/mineral security that could be commercially addressed by this technology;

- US Exclusive Economic Zone (EEZ) siting options with marine energy resource assessment alignment for: wave, tidal, current, and/or OTEC;
- Details of work to be performed in Phase I; and
- Phase II work.

Applicants should also detail how they propose to utilize the grant to advance the state-of-the-art, and, if successful, the commercialization plan for high value mineral extraction from the ocean using marine energy to be developed under this topic.

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

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15. WIND

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

The Office of Energy Efficiency and Renewable Energy's Wind Energy Technologies Office (https://energy.gov/eere/wind/wind-energy-technologies-office), seeks applications for innovations that significantly reduce the cost of energy from US wind power resources for land-based, offshore and distributed wind turbines. The Wind Energy Technologies Office (WETO) is seeking proposals for technology innovations with the potential to enable wind power to generate electricity offshore and in all 50 states cost competitively with other sources of generation.

Today, wind energy provides over 6% of the nation's total electricity generation. At the end of 2017, over 81,000 wind turbines, totaling 1,076 megawatts (MW) in cumulative capacity, were deployed in distributed applications across all 50 states, the District of Columbia, Puerto Rico, Guam, and the U.S. Virgin Islands. Additionally, 89 gigawatts (GW) of utility-scale wind turbines are installed across 41 states plus Puerto Rico and Guam. Finally, one of the smallest states in terms of both geographic size and installed wind capacity marked a major milestone in 2016, as the nation's first offshore wind project, the 30 MW Block Island project in Rhode Island, achieved commercial operation. With wind power generation exceeding 10% in 14 states, wind is a demonstrated clean, affordable electricity resource for the nation.

WETO aims to advance scientific knowledge and technological innovation to enable clean, low-cost wind energy options nationwide. WETO Research, Development, Demonstration and Deployment (RDD&D) activities are applicable to utility-scale land and offshore wind markets, as well as distributed turbines—

typically interconnected on the distribution grid at or near the point of end-use. Achieving LCOE goals will support deployment of wind at high penetration levels, sufficient to meet up to 20% of projected U.S. electricity demand in 2030, and up to 35% in 2050, compared to over 6% of demand in 2017. DOE plays a unique and valuable role in enabling the wind industry and its stakeholders to meet core challenges to industry growth through innovation to reduce wind technology costs and mitigate market barriers enables deployment and drives US economic growth.

All applications must:

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

Grant applications are sought in the following subtopics:

a. Coordinated and Secure Distributed Wind System Control and Communications Technologies

Early stage research and technology development is needed for higher penetrations of distributed energy resources (DERs) to integrate with existing electricity distribution networks, contribute to grid reliability, and provide resilience when the bulk power system fails. Interoperability between wind technology and other distributed energy resources (e.g. solar and storage) and the flexible electricity loads they support (e.g. buildings) can enable higher penetration through coordinated and secure controls and communications technologies. The goal of this subtopic is to make these capabilities available for wind energy technology, at all scales used in distributed applications, through the development of low-cost, validated and secure control and communication technologies. Proposals should address technical challenges related to wind technology specifically in Phase I, while addressing the common communication and cybersecurity requirements for all distributed energy resources. In addition, proposals should consider how to complement solar and/or storage technologies to advance the interests of multiple EERE programs in Phase II. [1, 2]

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

b. Remote Diagnostic Technologies to Reduce Offshore Wind Operating, Maintenance, and Repair Costs, and Increase System Reliability

Accessing an offshore wind turbine for service work is far more expensive than accessing a land-based wind turbine – technicians need to be transported long distances by boat, which requires more personnel and time, and can be delayed by weather. This, in turn, increases overall operations and maintenance (O&M) costs for an offshore wind plant, as well as lost revenue caused by unplanned downtime. Remote monitoring, inspection, and repair of offshore wind turbines and foundations can reduce O&M costs and avoid losses in energy production. To date, the field of remote diagnostics for offshore wind is not well-developed in the global marketplace and could benefit from adaptation of advanced technologies, materials and manufacturing processes being developed by U.S. firms for other applications. The larger scale, greater distances from shore, and generally harsher operating conditions of planned U.S. offshore wind projects compared to those in Europe, where most offshore development to date has taken place, provide an impetus for U.S. innovation in remote diagnostic technologies, while also resulting in significant global market potential.

WETO is seeking proposals for development or adaptation of innovative technologies to increase offshore wind plant operators' abilities to remotely monitor operating details of turbines and component subsystems in order to plan service events in advance of possible failures, and decrease the need for on-site technician time. Innovative technologies to be proposed may include hardware, sensors, instruments, and/or software tools. These technologies can facilitate maintenance and repair processes, such as: detection of a system operating outside of its normal parameters, inspection and identification of the root cause of the problem, quantification of how it will impact overall health of the machine, decision making on the proper course of action, and planning the repair or other preventative measures. If included as part of innovative hardware development, software may utilize advances in artificial intelligence and should ensure cyber security of the wind plant. WETO is seeking solutions to address a broad range of factors impacting reliability, therefore proposed technologies may be applicable to specific elements of an offshore system including blades, foundations, turbine mechanical, turbine electrical, and control electronics. Any hardware developed must be able to function reliably in harsh marine environments, and should integrate into the supervisory control and data acquisition (SCADA) system of the turbine and the wind plant. [3, 4]

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

c. Wind Turbine Blade Recycling

In addition to the specific subtopics listed above, WETO invites grant applications in other areas relevant to wind turbine blade recycling that enable wind power nationwide [5,6]. Of particular interest are applications which address the high investment and processing costs to recycle wind turbine blades through the development of new manufacturing techniques and/or materials that can facilitate recycling in the next generation of wind turbine blades.

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

References: Subtopic a:

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References: Subtopic c:

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16. JOINT TOPIC: ADVANCED MANUFACTURING AND SOLAR ENERGY TECHNOLOGIES OFFICES

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

The Advanced Manufacturing Office (AMO) collaborates with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance the global competitiveness of the United States [1].

The Solar Energy Technologies Office (SETO) supports early-stage research and development to improve the affordability, reliability, and performance of solar technologies on the grid. A specific effort is devoted to cutting-edge research and development that will help the solar industry to reduce the cost of manufacturing solar technologies to reach the 2030 cost targets [2, 3].

In this Topic, AMO and SETO seek applications for the development of innovative and impactful technologies that will support a strong solar manufacturing sector and supply chain in America, while producing cost-competitive modules that keep pace with the rising domestic and global demand for affordable solar energy. Applications must be responsive to the following subtopic. Applications outside of this area will not be considered. Within this topic, DOE is not interested in technologies and innovations related to racking optimization or mounting technologies. Applications in this space will be deemed non-responsive. However, any innovation in module form factors should have a line of sight to easy deployment using current or soon to come racking/mounting technologies.

Applications must:

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

Applicants are encouraged to leverage capabilities of consortia from both AMO and SETO. The Rapid Advancement in Process Intensification Deployments (RAPID) Institute is one of AMO's public-private R&D consortia where manufacturers, small businesses, universities, national laboratories, and state and local governments are brought together to pursue coordinated early-stage R&D in high-priority areas essential to energy in manufacturing, including module manufacturing [4]. SETO's Durable Module Materials (DuraMAT) Consortium [5], brings together national laboratories, universities, and industry to discover and develop new materials, testing methodologies, and designs for durable PV systems.

Grant applications are sought in the following subtopic:

a. Innovation in Solar Module Manufacturing Processes and Technologies

The global PV market has changed dramatically over the past years. Module prices have been decreasing rapidly and global deployment is experiencing strong growth. However, manufacturing is concentrated mainly in Asia [6]. Innovation-driven cost, performance and quality improvements, along with strong projected solar demand in the United States and across the Americas, could increase the attractiveness of US-based solar manufacturing. Although improvements to standard PV modules have produced deep cost reductions over the past years, the returns on such improvements appear to be diminishing, and more dramatic innovations in module design and manufacturing may be needed to maintain the path of rapid progress while opening further opportunities for domestic manufacturing.

Within the solar manufacturing value chain, module manufacturing represents one of the areas where innovation can be still introduced. Capital expenditures (CapEx) for a new module assembly line is lower relative to other components such as wafers and solar cell, but the process still requires several steps, some of them quite slow (e.g. lamination).

AMO and SETO are looking for new module manufacturing technologies, equipment development, individual process step innovation that can accomplish one or more of the following objectives:

- Modifications and repurposing of existing or dormant manufacturing technologies in order to utilize an existing infrastructure and demonstrate synergies with existing or new module technologies;
- Reduction of the number of steps in a module assembly (from cells or completed thin film device stack to completed module);
- Development of new tools or technologies that will increase the throughput of existing or new processes;
- Development of new module assembly technologies, methods and improved form factors that optimize module cost per wat;
- Development of module manufacturing methods that enable incorporation of new and upcoming cell technologies such as perovskite or other high efficiency solar cells such as monolithic module manufacturing methods;
- Development of new module technologies and equipment that lower the tool footprint or optimizes usage of the factory floor;
- Replacement of manufacturing bottlenecks (e.g. lamination, encapsulation) with faster and more efficient processes; and
- Development of techniques that could allow for the manufacture of mechanically staked or fully integrated tandem technologies.

In the Phase I of these projects, DOE expects applicants to analyze the feasibility of a new technology or process, identify and do preliminary work with relevant stakeholders to ensure easy access to facilities to test, validate, and prototype the new design. A prototype should be developed with the goal to embed or test it in a real-world assembly line or a dormant facility during Phase II.

Questions – Contact: solar.sbir@ee.doe.gov and Dickson Ozokwelu, Dickson.Ozokwelu@ee.doe.gov

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4. RAPID, American Institute of Chemical Engineers. https://www.aiche.org/rapid

5. Our Capabilities Network, Durable Module Materials Consortium. https://www.duramat.org/capabilities.html

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17. JOINT TOPIC: ADVANCED MANUFACTURING AND GEOTHERMAL TECHNOLOGIES OFFICES

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

The Advanced Manufacturing Office (AMO) collaborates with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance the global competitiveness of the United States [1].

The Geothermal Technologies Office (GTO) focuses on applied research, development, and innovations that will improve the competitiveness of geothermal energy, as to generate high-capacity factor dispatchable electricity, and in direct-use applications for heating and cooling of American homes and businesses. Domestic geothermal energy enables energy security, resiliency, and a strong domestic economy in emerging technologies [2].

In this Topic, AMO and GTO partner to solicit innovative research and development projects capable of addressing both critical material and critical water issues. This topic supports the priorities of the Acting Assistant Secretary for EERE to address (1) critical water issues: improve long-term access to clean, affordable water supplies, including technical challenges at the nexus of energy and water (energy used to produce clean water and water used in energy production) and identify ways to produce and ensure the availability of water during long term outages; and (2) critical materials: developing technologies to reduce the impediments to domestic critical materials production, finding alternatives to foreign-sourced critical materials, and developing technologies to reuse and recycle critical materials.

The Phase I application should detail design and bench scale systems that are scalable to a subsequent Phase II prototype development. Applications must be responsive to the following subtopic. Applications 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 baselines from the EERE Study [3];
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions;
- Include a preliminary cost analysis;
- Justify all performance claims with theoretical predictions and/or relevant experimental data.

Grant applications are sought in the following subtopics:

a. Geothermal Desalination and Critical Material Recovery Systems

Desalination systems take an impaired water source and produce fresh water and a concentrated brine waste stream. A typical source is seawater with approximately 35,000 ppm total dissolved solids (TDS), but other sources can include coal tailing, industrial waters, and produced waters from oil and gas, which have higher TDS. The concentrated brine byproduct is a good target for mineral recovery operations because the critical material(s) of interest will occur in higher concentrations which may improve the economics for their recovery.

To be responsive to this topic, the small business must propose a research and development project that aims to commercialize a system that will accomplish both desalination and recovery of a critical material. For this subtopic, the process must use a geothermal heat source. Specifically, the system must yield fresh water with less than 500 ppm TDS while recovering at least one critical material, which can include, but is not limited to, rare earth elements. A comprehensive list of 35 mineral commodities deemed critical under the definition from Executive Order 13817 was recently published by the Secretary of the Interior [4].

Because the material recovery and water processing scale differently to address their commercial needs, it is recommended that each applicant select a primary goal for their system (i.e. design a critical material recovery system that is capable of treating water or vice versa). The current benchmark for thermal seawater desalination is multi-stage flash whose energy intensity is estimated at 15 kWh per meter cubed with approximately 11 kWh coming from thermal energy [3]; however, more efficient thermal desalination systems are currently under development and energy intensity can vary increase significantly for higher TDS source waters.

Under this subtopic, the system must be tailored to make use of geothermal heat, with low temperature geothermal resources (<150 °C) being of particular interest in this application. These resources can come from lower temperature geothermal reservoirs or from cascaded applications from higher temperature geothermal resources. The impaired water sources primarily of interest in this subtopic are geothermal brines and produced waters from oil and gas.

Questions – Contact: Joshua Mengers, joshua.mengers@ee.doe.gov

b. Desalination and Critical Material Recovery Systems from Other Energy Sources
In addition to the specific subtopic listed above, the Department also solicits applications that fall within the specific scope of the topic description above. Specifically, this subtopic will allow systems that use energy sources other than geothermal and will focus on systems that propose improvements in energy efficiency by at least 30%. The baseline for current typical energy intensity for seawater desalination is reverse osmosis at 3.3 kWh per cubic meter yielding costs of nearly $2 per cubic meter [3].

Questions – Contact: Robert Gemmer, bob.gemmer@ee.doe.gov

References:

1. Advanced Manufacturing Office, U. S. Department of Energy. https://energy.gov/eere/amo

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

3. Energy Efficiency & Renewable Energy, 2017, Bandwidth Study on Energy Use and Potential Energy Savings Opportunities in U.S. Seawater Desalination Systems, U.S. Department of Energy, p. 116. https://www.energy.gov/sites/prod/files/2017/12/f46/Seawater_desalination_bandwidth_study_2017.pdf

4. Office of the Secretary, Interior, 2018, Final List of Critical Minerals 2018, Federal Register, Vol. 83, Issue 97, p. 23295-23296. https://www.gpo.gov/fdsys/pkg/FR-2018-05-18/pdf/2018-10667.pdf

18. JOINT TOPIC: ADVANCED MANUFACTURING AND FUEL CELL TECHNOLOGIES OFFICES

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

The Advanced Manufacturing Office (AMO) collaborates with industry, small business, universities, and other stakeholders to identify and invest in emerging technologies with the potential to create high-quality domestic manufacturing jobs and enhance the global competitiveness of the United States [1].

The Fuel Cells Technologies Office (FCTO) focuses on applied research, development, and innovation to advance hydrogen and fuel cells for transportation and diverse applications enabling energy security, resiliency, and a strong domestic economy in emerging technologies [2].

Applications must:

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

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

Applications are sought in the following subtopic:

a. Advanced Materials for Detection and Removal of Impurities in Hydrogen

High-performance membrane technologies have been explored in recent years for their potential to detect and remove contaminants from streams of hydrogen gas, to serve applications requiring high purities (e.g. petroleum refineries, glassmaking plants or hydrogen fueling stations) [3]. Today, the primary approaches to management of contamination are (1) pressure swing adsorption techniques at centralized hydrogen production facilities, and (2) distribution infrastructure technologies to mitigate the introduction of contaminants. Nevertheless, excursions can take place. Examples of sources of potential contamination include lubricating oil in compressors, off-gassing from polymers, or residual water from steam methane reformers or electrolysis [3]. Contaminants can permanently deactivate catalysts (e.g. within upgrading equipment at refineries, or in fuel cells onboard vehicles). Current inline detectors at hydrogen filling stations for fuel cell vehicles are incapable of removing contaminants, or shutting down a dispenser in time to prevent them from reaching the vehicle.

This subtopic seeks concepts that can both detect and remove high-priority contaminants from hydrogen fuel. Concepts proposed should be capable of continuous operation at 875 bar and -40°C, such that the unit developed can be installed immediately upstream of a hydrogen dispenser. Contaminants of particular interest, based on their likelihood of occurrence and the level of damage they can do to a fuel cell, are: water, carbon monoxide, total sulfur, ammonia, and total hydrocarbons [4]. Phase I of proposed projects should develop and evaluate potential materials that are capable of removing water, carbon monoxide, sulfur, and hydrocarbons from hydrogen fuel at stations to SAE J2719 levels [5], and design a concept that can both detect and remove contaminants. The designed system should be easily removable and replaceable once the expected lifetime expires. Concepts proposed should target a capital cost of <$5,000 and an annual operating cost of <$1,100. Phase II may include the development and experimental evaluation of a prototype.

Questions – Contact: Neha Rustagi, neha.rustagi@ee.doe.gov and David Forrest, david.forrest@ee.doe.gov

References:

1. Advanced Manufacturing Office, U.S. Department of Energy. https://energy.gov/eere/amo

2. Fuel Cell Technologies Office, U.S. Department of Energy. https://www.energy.gov/eere/fuelcells/fuel-cell-technologies-office

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4. Terlip, D., Ainscough, C., Buttner, W., and McWhorter, S., 2015, H2FIRST Hydrogen Containment Detector Task, National Renewable Energy Laboratory, Sandia National Laboratories, p. 31. https://www.nrel.gov/docs/fy15osti/64063.pdf

5. Fuel Cell Standards Committee, 2011, Hydrogen Fuel Quality for Fuel Cell Vehicles, SAE International. https://www.sae.org/standards/content/j2719_201109/

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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 Groundwater and Soil Remediation focuses on four areas of applied research including the Attenuation-Based Remedies for the Subsurface Applied Field Research Initiative (Savannah River Site), the Deep Vadose Zone Applied Field Research Initiative (Hanford Site), the Remediation of Mercury and Industrial Contaminants Applied Field Research Initiative (Oak Ridge Site), and Advanced Simulation Capability for Environmental Management.

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.

19. 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

DOE's Environmental Management Program is leading an effort to develop new methods and processes to attenuate contaminants in the subsurface and improve the ability to monitor that attenuation process. The intention is to eliminate costly pump and treat systems as the contaminant levels diminish while assuring the public and regulator community that we are protecting human health and the environment.

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

a. Leak Integrity Inspections of Aging Critical Infrastructure with Remote Inspection Non-Destructive Evaluation Technology (NDE)

Underground high-level waste (HLW) storage tanks provide critical interim storage of nuclear legacy waste prior to its processing and permanent disposal. The leak integrity of the tanks must be maintained to support waste processing and waste disposition. In-service inspections are performed on physically accessible regions of primary tank sidewalls and secondary liner bottoms to assess HLW tank leak integrity.

However, the failure of an in-service HLW tank due to degradation of the primary tank bottom would demonstrate the need to include a limited-access tank region in the scope of HLW leak integrity inspections.

The feasibility of using guided wave ultrasound to perform volumetric examinations several feet away/around a sensor have been demonstrated for primary tank bottom inspections. Robotic visual inspection feasibility has also recently been demonstrated. There is an opportunity to expand volumetric examination technology options for leak integrity inspection of both HLW primary tank bottoms and secondary liner bottoms by leveraging NDE technology advancements made over the past decade. Examples include guided wave electromagnetic acoustic transducers, ultrasonic phased-array transducers and pulsed eddy current. Successful demonstrations of the ability of NDE technology to meet flaw detection capability and performance requirements would justify the need to develop robotic deployment systems. Therefore, NDE technology is the focus of this topic.

NDE sensors for inspection of 1/2 in. and 7/8 in. thick carbon steel primary tank bottom plates and welds would be allowed direct contact with limited plate surface areas. The sensor would need to provide a balance between flaw detection capability/performance and cover ranges of at least 24 in. adjacent to the sensor to allow plates/welds to be inspected that are physically inaccessible and covered by insulating concrete (refractory) material. NDE sensors for primary tank bottom inspection would ultimately also need to balance size, payload/power/positioning performance requirements that are considered practical for a robotic deployment subsystem and need to tolerate oxidized/rusted/dirty surfaces, temperatures up to 200°F, and gamma radiation dose rates of up to 300 R/hr. NDE sensors for inspection of 3/8 in. thick carbon steel secondary liner bottom plates and welds would need to meet similar requirements to those for primary tank bottom NDE sensors; however direct contact with the plate surfaces would not be allowed and inspections would need to be performed through approximately six inches of refractory material. The deployment of single NDE sensors for each inspection application is preferred.
This particular need could be applicable to other industries with effluents that are contained and stored in tanks such as the oil and gas industry or wastewater treatment facilities. Additional application of the sensors might benefit the Department of Defense that have heavy metal and solvent contamination problems.

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

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2. Savannah River Remediation LLC, 2012, Performance Assessment for the H-Area Tank Farm at the Savannah River Site, SRR-CWDA-2010-00128, Rev. 1, p. 850. https://sro.srs.gov/docs/SRR-CWDA-2010-00128_R1_Part%201.pdf.

3. Moran, T.L., Larche, M. R., Denslow, K. M., and Glass III, S.W., 2017, NDE Technology Development Program for Non-Visual Volumetric Inspection Technology – Technology Screening Report, Pacific Northwest National Laboratory, PNNL-26328, Rev. 0, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26328.pdf

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5. Moran, T.L., Larche, M. R., Denslow, K. M., and Glass III, S.W., 2018, NDE Technology Development Program for Non-Visual Volumetric Inspection Technology – Phase I Summary Report, Pacific Northwest National Laboratory, PNNL-26924, Rev. 1, http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-26924REV1.pdf.

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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.

20. CARBON STORAGE 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

CORE STORAGE R&D—Core Storage R&D involves both applied laboratory- and pilot-scale research focused on developing new technologies and systems for geologic storage. Core Storage R&D encompasses three Technology Areas: (1) Geologic Storage Technologies and Simulation and Risk Assessment; (2) Monitoring, Verification, Accounting (MVA), and Assessment; and (3) Carbon Use and Reuse.

For the Carbon Use and Reuse Technology Area, the objective of the research is to boost the commodity market for CO_2. The metric is to develop utilization technologies that cost less than $10 per metric ton of CO_2 while making no additional contribution to CO_2 emissions. The concept of converting CO_2 into a valued product and commodity, and possibly accelerating the implementation of CCS, has attracted interest worldwide.

DOE is the lead agency supporting research and development of technologies to ensure that greater than 99% of injected CO_2 remains permanently stored in deep geologic formations. Carbon storage research conducted in the near and long term will augment existing technologies to ensure permanent storage of CO_2 for the emerging CO_2 storage industry.

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

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

Grant applications are sought in the following subtopics:

a. High Volume Subsurface Monitoring Data Processing and Minimization

In order to ensure permanent storage of CO_2 in the subsurface, a complex network of sensors are being developed to monitor and track the migration and location of CO_2 during and after injection operations. The data from these sensing and monitoring sources needs to be transmitted to the surface, integrated, and analyzed so that storage security can be confirmed and decisions can be made relative to operations. The volume of data from these sources is expected to be significant and presents a challenge in terms of transmitting to the surface.

NETL is seeking applicants to build the capability to reduce or better manage these large volumes of data from new monitoring systems that include distributed fiber systems, nanosensors, and passive and continuous source monitoring. Current systems are limited in terms of bandwidth and data storage. Edge computing (e.g., Raspberry pi) is technology option that can help manage such large volumes of data by performing some of the needed analysis at the top of the well, or perhaps even downhole.

Grant applications are sought with the capability to reduce the volumes of data that need to be transmitted or stored by pre-processing the data to create smaller volumes of derivative data to enable real-time decision making. Some of the technical challenges that will need to be overcome to achieve this goal are: 1) the ability to migrate new algorithms from the cloud (where they are developed) to the edge (where they are needed for continuous improvement); 2) the ability to integrate derivative data from multiple edge locations; and 3) the ability to accommodate the heterogeneity of various hardware/software platforms that exist at a site.

Questions - Contact: Andrea McNemar, andrea.mcnemar@netl.doe.gov

b. Telemetry Systems for Deep Subsurface Monitoring

A "Monitoring, Verification, and Accounting (MVA)" program is designed to confirm permanent storage of carbon dioxide (CO_2) in geologic formations through monitoring techniques that are reliable and cost effective. Monitoring technologies are used to ensure that the location of the CO_2 is confirmed and that the CO_2 will remain within the injection reservoir. Critical to this effort is the placement of sensors (pressure sensors, geochemical sensors, etc.) in direct contact with the various reservoirs (injection reservoir, above-zone monitoring interval) to perform real-time monitoring of meaningful parameters. Operating permits for geologic storage projects under the Safe Drinking Water Act and Clean Air Act require this monitoring to account for stored CO_2 and to ensure that potable groundwater sources and sensitive ecosystems are protected.

Presently there are two methods utilized to deploy real-time sensors in contact with a reservoir: a) inside a well casing with perforations through the casing and cement annulus, with an umbilical strapped to the tubing, or b) mounted on the outside of the well casing in the cement annulus, with the umbilical running up the outside of the casing in the annulus. Putting the sensors inside casing requires the well to be completed for full well control, with acid-resistant casing, tubing, packer assembly, and wellhead. Placing the sensor outside of an unperforated casing allows for easier well completion and access for time-lapse logging, VSP, etc., but the umbilical in the annulus is a potential CO_2 leakage pathway.

Grant applications are sought for advanced telemetry systems, while maintaining the integrity of the well, eliminate the need for an umbilical in the annulus for external casing sensors that are utilized for real-time monitoring. Since the sensor is permanently placed in a cement-filled annulus, a robust and stable telemetry system is required to power the sensor and transmit the acquired data to monitoring systems at the surface. These downhole telemetry systems will be required to operate at minimal reservoir conditions—pressure 5,000 psi, temperature 150 ° F, and in the potentially low-pH environment of a CO_2-filled saline reservoir with minimal total dissolved solids (TDS) of 100,000. The system can be tailored to a specific sensor but preference will be given to systems that will service a variety of downhole sensors.

Questions - Contact: Andrea McNemar, andrea.mcnemar@netl.doe.gov

c. Nanosensors for Deep Subsurface Reservoir Monitoring

Subsurface storage of CO_2 requires a suitable setting at significant depth from the surface (greater than 2,500 feet depth). Monitoring regimes for carbon storage are utilized to confirm the location of the CO_2, assuring that it remains contained, and assessing potential future risks posed by the injected CO_2. Given the depth and extreme conditions, monitoring and tracking of the injected CO_2 presents a challenge.

Currently, monitoring methods that are deployed on the surface or through a vertical wellbore are the only mechanisms available to monitor the CO_2 storage reservoirs. These take two forms; a) well-based downhole sensors that investigate a small area in close proximity to the well with high resolution, and b) non-invasive forms of three-dimensional imaging from the surface (e.g. time-lapse surface seismic) that monitor over large areas but with greatly reduced resolution and inherent repeatability issues due to the operating environment.

Grant applications are sought to perform high-resolution 3D monitoring of injected CO_2 from inside the reservoir utilizing nanoparticles. These nanoparticles must be small enough in size to freely move through the formation pores to clearly monitor CO_2 or measure reservoir properties (e.g., porosity and permeability), or mineral distribution, or pressure, or stress throughout the reservoir at high resolution. Potential parameters for the nanoparticles to monitor could include reservoir pressure, water salinity, fluid pH, fluid geochemistry, or CO_2 concentration.

Questions - Contact: Andrea McNemar, andrea.mcnemar@netl.doe.gov

d. CO_2 Use and Reuse – Plasma Technologies

With over 5 billion metric tons of CO_2 emissions in the United States in 2017, utilization and conversion of CO_2 into value-added chemicals, fuels, polymers, building materials, and other carbon-based products represents a key economic opportunity. CO_2 use and reuse technologies can reduce overall CO_2 emissions and offset CO_2 capture costs by generating valuable products. In addition to CO_2 emissions from electric power, industrial CO_2 emissions provide an opportunity for utilization of CO_2 under different conditions and concentrations and may prove to be more applicable for CO_2 use and reuse technologies. The objective of the DOE carbon use and reuse R&D effort is to develop technologies with the potential to transform CO_2 in valuable products in an efficient, economical and environmentally-friendly manner. The use of CO_2 to produce products may require less energy, less reagents, and generate less waste than production from petroleum or natural gas feedstocks, which can significantly lower life-cycle carbon footprints. CO_2 conversion, either by pure CO_2 splitting or conversion in combination with a co-reactant such as CH_4, H_2, or H_2O, can be energy intensive due to the high thermodynamic stability of CO_2, and will require novel and innovative technologies to become commercially viable. Plasma technologies have many advantages over traditional CO_2 conversion pathways and may provide a unique and economical process for the utilization of anthropogenic CO_2.

Plasma technologies provide gas activation by energetic electrons instead of heat, allowing thermodynamically difficult reactions, such as CO_2 splitting, to occur with reasonable energy costs. Plasma technologies can also be easily switched on and off which is compatible with intermittent renewable energy and load-following applications. The most common types of plasma reported in the literature are dielectric barrier discharges (DBDs), microwave (MW), and gliding arc (GA); however, other types, such as radiofrequency, corona, glow, spark, and nanosecond pulse discharges, have also been studied in the literature. Depending on the type of plasma, different CO_2 conversions and energy efficacies have been reported. In terms of energy efficiency, a target of at least 60 percent energy efficiency has been suggested for plasma CO_2 conversion to be competitive with other technologies. Plasma tends to be very reactive and not selective in the production of targeted compounds. Therefore, plasma CO_2 conversion technologies may need a catalyst to increase selectivity and produce targeted compounds. Low conversion of CO_2 could also require postreaction separation of the products from the reactants and may be cost prohibitive.

Proposals are sought to convert CO_2 to high value chemicals or fuels using plasma technologies in an economically viable process, overcoming challenges associated with energy efficiency, CO_2 conversion and selectivity.

Questions - Contact: Andrea McNemar, andrea.mcnemar@netl.doe.gov

e. Other

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

Questions – Contact: Andrea McNemar, andrea.mcnemar@netl.doe.gov

References: Subtopics a,b,c:

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

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21. RARE EARTH ELEMENTS AND CRITICAL MINERALS

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-FE and NETL is supporting the research and development of technologies to economically extract rare earth elements (REEs) and critical minerals (CMs) in an environmentally sustainable manner from coal and coal byproducts which includes, but is not limited to, acid mine drainage, mine tailings, fly ash and other legacy waste streams. Upcoming research in the near and long term must optimize existing extraction, separation, and purification technologies as well as investigate transformational, novel approaches to support a sustainable domestic critical mineral industry.

To achieve commercial development of coal and coal byproducts for rare earth elements and other critical minerals, priority research areas for this program include resource characterization; developing portable, durable field analysis instrumentation; improving conventional processing to reduce costs and environmental impacts; transformational methods or processes to simultaneously extract and purify elements to increase efficiency; and prioritize creating an innovative business case for REE and CM projects including the use of modular systems, generating diverse product streams, and adaptive processing.

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

Grant applications are sought in the following subtopics:

a. Production of Rare Earth Metals

The nation needs rare earths to manufacture modern technology, but almost all REEs are imported from China. In 2017, DOE and NETL reported to Congress that coal and coal by-products could be viable sources for a domestic supply of rare earths. While this discovery could potentially place the nation on a path to independence from foreign sources of REEs, many technical challenges still remain to be addressed.

The technical feasibility of extracting REEs from coal and coal-based resources was demonstrated in 2017-2018 during conduct of DOE-NETL's Feasibility of Recovery of Rare Earth Elements Program which had been initiated in 2014. Currently efforts in the REE Program are being focused on demonstrating the economic feasibility and scale-up to small pilot-scale prototype extraction, separation and recovery systems, producing high purity, salable, rare earth element oxides (REOs) in FY2020.

As individual high purity rare earth oxides, phosphates or fluorides, these materials are often used as automotive pollution-abatement catalysts (oxides), fluorescent lamps (phosphates), and electrowinning electrolytes (fluorides). 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.

"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." The objective of this SBIR, Production of Rare Earth Metals, is (1) to expand technology development beyond producing salable REOs from coal-based resources, ultimately producing rare earth metals (REMs) for use in intermediate and/or end product commercial and/or defense equipment; and additionally (2) to advance technology beyond the current state-of-the-art which 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 to produce rare earth metals (REMs) – an integral part for generating a total domestic product supply chain. 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.

This SBIR efforts shall include:

- Development of advanced new/novel rare earth oxide-to-rare earth metal (REO-REM) reduction techniques
- Production and analytical characterization of small quantities of high purity individual REMs resulting from advanced new/novel REO-REM reduction processes

Questions – Contact: Charles Miller, charles.miller@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: Charles Miller, charles.miller@netl.doe.gov

References: Subtopic a:

1. Humphries, M., 2013, Rare Earth Elements: The Global Supply Chain, Congressional Research Service, p. 27. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwi3xPy6l4HeAhUMmeAKHexDAvEQFjAAegQICRAC&url=https%3A%2F%2Ffas.org%2Fsgp%2Fcrs%2Fnatsec%2FR41347.pdf&usg=AOvVaw1KrTp2hmN-oZh1OISixiGO

   Lucas, J., Lucas, P., Le Mercier, T., et al, 2014, Rare Earths: Science, Technology, Production and Use, Elsevier Inc., p. 370, ISBN: 9780444627445. https://arizona.pure.elsevier.com/en/publications/rare-earths-science-technology-production-and-use

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22. OIL & NATURAL GAS

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

While the United States (US) natural gas midstream and transmission systems are extensive, the development of unconventional oil resources in multiple basins—in particular the Permian Basin in Texas and the Williston Basin in North Dakota—has outpaced the construction of pipeline take-away capacity. This lack of capacity has resulted in increased levels of natural gas flaring and in some instances, oil production delays. The expansion of natural gas infrastructure is time consuming due to increased permitting hurdles and competition for construction crews from other infrastructure projects. These challenges, coupled with limits on flaring volumes, pose a barrier to efficient development of US unconventional oil resources and realization of the local and national economic benefits that accrue with that development. Flaring natural gas is also a waste of a valuable natural resource. New technologies or processes to effectively capture and utilize this methane, as well as to reduce associated emissions, will provide multiple benefits including economic gains.

In some cases, pipeline capacity expansions will alleviate the problem by providing market access within a reasonable time frame. However, significant flaring will likely continue due to a combination of remote well pads, variation in associated gas volumes, well drilling and completion schedules, and oil and natural gas market conditions. Furthermore, as emerging tight oil plays are developed, this situation will likely be repeated time and again. A number of commercial or pre-commercial technologies exist for capturing natural gas and converting it into marketable products when direct sale of the gas is not feasible. These technologies include: gas volume reduction through NGL extraction, gas liquefaction (LNG), Fischer-Tropsch conversion of methane to diesel (gas-to-liquids or GTL), compression to CNG, conversion to methanol or other chemical products, and conversion to electricity for use in the field via micro-turbines. However, most of these commercial technologies, even at modest scales, require a large footprint (multiple tractor trailer sized equipment packages) and capital expense that has precluded them from serving as a viable alternative to flaring.

Further, each unconventional play has its own specific characteristics that make such solutions more or less applicable in any given case. These characteristics include: well density and remote location, variable gas volumes and rates over time, variable field gas pressure, variable gas composition (including carbon dioxide content), nature of existing infrastructure, distance to markets, ownership and legal issues, and state permitting regulations, among others.

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

Grant applications are sought in the following subtopics:

a. Technologies for Capturing and Converting Natural Gas to Useful Products to Reduce Flaring
Development of conversion technologies and processes that would be effective over a wide range of conditions will require breakthroughs in the areas of process intensification and modularization. The ideal

technology would possess high conversion and selectivity, and involve a minimum number of process steps. High reaction and mass and heat transfer rates will be necessary to minimize equipment size, while lower energy inputs will be required due to the lack of utility services at remote locations. Mobile systems that can be easily commissioned, de-commissioned and relocated to a new site are desirable.

Proposals are solicited for the development of transportable, modular systems for capturing and converting natural gas to usable products (e.g., CNG, LNG, GTL products, chemicals, electricity) in the field as an economic alternative to flaring. Such proposals could involve (but are not limited to):

- Robust and energy efficient small footprint (single trailer load sized), modular systems (including gas separation, treatment and compression) capable of converting relatively limited volumes of low pressure associated natural gas streams of variable composition into a methane supply suitable as an inlet feed for commercial micro-turbine generator or small scale conversion systems (e.g., LNG, GTL),
- Small footprint (single trailer load sized), robust, energy efficient systems capable of converting a methane gas stream inlet feed volume consistent with a typical associated gas flare, via into GTL diesel, methanol or other liquid or solid chemical products,
- Novel, small footprint, modular, robust and energy efficient technologies for the direct conversion (i.e., not including a syngas production step) of natural gas streams into solid or liquid chemical products.

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

References: Subtopic a:

1. National Energy Technology Laboratory, Oil and Natural Gas Program, U.S. Department of Energy. http://www.netl.doe.gov/technologies/oil-gas/index.html

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PROGRAM AREA OVERVIEW: OFFICE OF FUSION ENERGY SCIENCES

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

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

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

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

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

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

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

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

IMPORTANT CHANGE FOR FY 2019: FES is reducing the number of SBIR/STTR topics and subtopics beginning in FY 2018. This action is being taken because FES has historically received a much greater number of high quality proposals that it cannot fund each year. The impact for FY 2019 is that the following topics and subtopics will not be included in FY 2019, but are planned to be included in FY 2020.

- PLASMA APPLICATIONS
- Low-Temperature Plasma Science and Engineering for Plasma Nanotechnology

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- Low-Temperature Plasma Chemistry for a Cleaner Environment

23. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS

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

Future fusion reactors will present a uniquely hostile environment that includes combinations of high temperatures, reactive chemicals, large thermal-mechanical stresses, exposure to high energy plasmas, and damaging neutron radiation. Developing materials, components, and technologies that not only survive the extreme fusion environment but also meet objectives for performance, safety, and environmental attractiveness is an unprecedented challenge. This program is thus interested in proposals aimed at resolving key scientific and technical hurdles as described in the subsections below.

Additionally, a recent Fusion Energy Sciences Advisory Committee (FESAC) was charged with identifying "the most promising transformative enabling capabilities (TEC) for the U.S. to pursue that could promote efficient advances toward fusion energy, building on burning plasma science and technology." In their subsequent report, the FESAC subcommittee identified four tier one TEC's which were defined as having the potential to dramatically increase the rate of progress towards fusion. These four TEC's are advanced algorithms, high critical temperature superconductors, advanced materials, and novel technologies for tritium fuel cycle control. Proposals are therefore encouraged to explore opportunities for leveraging these TEC's in order to address the topical areas below. The full TEC report can be seen here:
https://science.energy.gov/~/media/fes/fesac/pdf/2018/TEC_Report_15Feb2018.pdf

a. Plasma Facing Components

The plasma facing components (PFCs) in energy producing fusion devices will experience unprecedented high heat, particle, and neutron fluxes, leading to large perturbations and reconstitution of the base material over the lifetime of the PFC. The goal of this program is to establish the feasibility of PFCs that meet demanding requirements for performance, core compatibility, and safety.

Grant applications are sought for:
Development of solid PFCs. These PFCs are typically envisioned as 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. Research is sought to explore: (1) innovative tungsten alloys having good thermal conductivity, resistance to recrystallization and grain growth, improved mechanical properties (e.g., strength and ductility), and resistance to thermal fatigue; (2) novel coatings or bulk specialized low-Z materials for improved plasma performance; (3) innovative heat sink and component designs for enhanced cooling; and (4) innovative joining and fabrication methods for PFC manufacturing.

Development of liquid metal PFCs. Materials of interest included liquid lithium, gallium, tin, or mixture thereof. Concepts of interest include thin film systems (up to cm scale) with flow speeds ranging from stagnant to fast flow. Research is sought to explore: (1) techniques for the replenishment and control of stagnant liquid metal surfaces; (2) techniques for the production, control, and removal of flowing liquid metal thin films (velocity 0.01 to 10 m/s); (3) advances in materials and interfaces that allow for the production and control of uniform, well-adhered films; and (4) techniques for active control of liquid metal surface and flow stabilization in the presence of plasma instabilities (time and space varying magnetic field).

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

b. Blanket and Safety Technologies

The breeder blanket is a complex, multi-function, multi-material engineered system that is designed to efficiently convert fusion power into electricity and breed tritium fuel by capturing fusion neutrons in lithium. In addition to the blanket, various other systems requirements include heat transport loops and exchangers, tritium processors, nuclear shielding, and sensor arrays. The goal of this program is to address the challenges in harnessing fusion power through developing a safe and efficient fuel and heat extraction system required for a self-sufficient, electricity-generating fusion reactor.

Grant applications are sought for:

Development of solid breeder blanket materials, concepts, and technologies. Research is sought to explore: (1) high density (up to~80%) and/or high breeding ratio materials; (2) materials with increased structural integrity, thermo-mechanical properties, and absence of major geometry changes (such as sintering in pebble beds) in intense radiation environment; (3) concepts with increased thermal conductivities and contact (as opposed to point contacts between pebbles and walls); and (4) tools for simulation and analysis of materials and systems for solid breeders that leverage advanced computational techniques.

Development of liquid breeder materials, concepts, and technologies. Research is sought to explore: (1) high breeding capacity materials and designs; (2) innovative breeder materials that are not influenced by the magnetohydrodynamic (MHD) effect, can operate at high temperatures (400-700 ˚C), have increased chemical compatibility with current generation reduced activation materials (RAFM steels, ODS steels, SiC, W), and are conducive to tritium extraction; and (3) tools for simulation and analysis of materials and systems for liquid breeders that leverage advanced computational techniques.

Development of tritium fuel cycle management and processing techniques. Research is sought to explore: (1) tritium (hydrogen) extraction and purification technologies for proposed breeder, coolant, and liquid PFC working fluids (Li-Pb, He gas, Li, Sn, Ga); (2) simulation tool to predict and model tritium production, transport, and retention within coolant/breeder loops; and (3) plant level tritium management, containment, and safety tools and systems development.

Development of requisite breeder blanket diagnostics such as liquid metal flow sensors, tritium concentration sensors, etc.

Development of neutronics simulation tools for systems level analysis. Tools are sought to explore: (1) prediction of the fusion Tritium Breeding Ratio (TBR) in breeder blankets; (2) material irradiation damage calculations, including both displacement and transmutation effects as a function of position and fluence; and (3) prediction of residual radioactivity for safety and remote handling considerations. Ideally these tools are plug-ins or compatible modules within existing commercial design software codes to enhance the integration, validation, and adoption of the tools.

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

c. Superconducting Magnets and Materials

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

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

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

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

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

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

d. Structural Materials and Coatings

Fusion materials and structures must function for a long time in a uniquely hostile environment that includes combinations 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 for:
Development of current generation reduced activation ferritic martensitic (RAFM) steels technologies, with a focus on joining and fabrication techniques. 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. Appropriate fabrication technologies

must produce components within dimensional tolerances, while meeting minimum requirements on mechanical and physical properties.

Development of 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).

Development of functional materials and coatings for use in fusion reactors. System applications of high priority include the Pb-Li breeder blanket concept and liquid metal (lithium, tin, and gallium) PFC concepts. Research is sought to explore: (1) materials compatibility issues; (2) tritium (hydrogen) permeation barriers; and (3) electrical insulation materials (to reduce the pressure drop due to the magneto-hydrodynamic (MHD) effects). Proposals must include considerations towards compatibility with the coated structural alloy and/or working fluid for long-time operation at elevated temperatures (500-700˚C), including cyclic thermal loading, and potential application issues associated with implementation on large-scale system components.

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

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References: Subtopic d:

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

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

24. FUSION SCIENCE AND 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

The Fusion Energy Sciences program currently supports several fusion-related experiments with many common objectives. These include expanding the scientific understanding of plasma behavior and improving the performance of high temperature plasma for eventual energy production. The goals of this topic are to develop and demonstrate innovative techniques, instrumentation, and concepts for (a) measuring magnetized plasma parameters, (b) for low-temperature and multi-phase plasmas, (c) simulation, control, and data analysis for magnetically confined plasmas, and (d) small scale experiments on stellarators, spherical tori, and reversed field pinches. It is also intended that concepts developed as part of the fusion research program will have application to industries in the private sector. Further information about research funded by the Office of Fusion Energy Sciences (FES) can be found in the FES website at http://science.energy.gov/fes/.

Grant applications are sought in the following subtopics:

a. Diagnostics

Diagnostics are key to advancing our ability to understand, predict, and control fusion plasmas. Applications are sought for the development of advanced diagnostic techniques and technology to (i) enable new ways of studying plasma behavior in both existing and new plasma regimes, (ii) measure plasma parameters not previously accessible, (iii) increase the capabilities of existing diagnostics, and/or (iv) reduce substantially the complexity of existing diagnostics. Development of diagnostics meeting the needs for advancing the science of burning plasmas, boundary and pedestal physics, transient events (including ELMs and disruptions), plasma-material interactions, and long-pulse magnetized plasmas are particularly welcome. Proposals that have also a broader applicability are encouraged.

All applications should specifically identify the strong potential for commercialization of the proposed innovations on a schedule that is consistent with the award timeline and sequence of the DOE SBIR and STTR Programs. Ideally, the proposed customer base should extend into the private sector. Accordingly, work that is normally funded by program funds, or that culminates only in the awarding of future program funds, should not be proposed. Furthermore, requests seeking funding for the routine application or operation of mature diagnostic techniques will not be considered.

Questions – Contact: Matthew Lanctot , matthew.lanctot@science.doe.gov

b. Components for Heating and Fueling of Fusion Plasmas

Grant applications are sought to develop components related to the generation, transmission, and launching of high power electromagnetic waves in the frequency ranges of Ion Cyclotron Resonance Heating (ICRH, 50 to 300 MHz), Lower Hybrid Heating (LHH, 2 to 10 GHz), and Electron Cyclotron Resonance (or Electron Bernstein Wave) Heating (ECRH / EBW, 28 to 300 GHz). These improved components are sought for the microwave heating systems of the fusion facilities in the United States and facilities under construction including ITER. Components of interest include power supplies, high power microwave sources or generators, fault protection devices, transmission line components, and antenna and launching systems. Specific examples of some of the components that are needed include tuning and matching systems, unidirectional couplers, circulators, mode convertors, windows, output couplers, loads, energy extraction systems from spent electron beams and particle accelerators, and diagnostics to evaluate the performance of these components. Of particular interest are components that can safely handle a range of frequencies and increased power levels.

For the ITER project, the United States will be supplying the transmission lines for both the ECRH (2 MW/line) system, at a frequency of 170 GHz, and for the ICRH system (6 MW/line), operating in the range of 40 – 60 MHz. For this project advanced components are needed that are capable of improving the efficiency and power handling capability of the transmission lines, in order to reduce losses and protect the system from overheating, arcing, damage or failure during the required long pulse operation (~3000s). Examples of components needed for the ECRH transmission line include high power loads, low loss miter bends, polarizers, power samplers, windows, switches, and dielectric breaks. Examples of components needed for the ICRH transmission line include high power loads, tuning stubs, phase shifters, switches, arc localization methods, and in line dielectric breaks. For the ECRH and ICRH ITER transmission lines, improved techniques are needed for the mass production of components, in order to reduce cost. Lastly, advanced computer codes are needed to simulate the radiofrequency, microwave, thermal, and mechanical components of the transmission lines.

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

c. Simulation and Data Analysis Tools for Magnetically Confined Plasmas

The predictive simulation of magnetically confined fusion plasmas is important for the design and evaluation of plasma discharge feedback and control systems; the design, operation, and performance assessment of existing and proposed fusion experiments; the planning of experiments on existing devices; and the interpretation of the experimental data obtained from these experiments. Developing a predictive simulation capability for magnetically confined fusion plasmas is very challenging because of the enormous range of overlapping temporal and spatial scales; the multitude of strongly coupled physical processes governing the behavior of these plasmas; and the extreme anisotropies, high dimensionalities, complex geometries, and magnetic topologies characterizing most magnetic confinement configurations.

Although considerable progress has been made in recent years toward the understanding of these processes in isolation, there remains a critical need to integrate them in order to develop an experimentally validated integrated predictive simulation capability for magnetically confined plasmas. In addition, the increase in the fidelity and level of integration of fusion simulations enabled by advances in high performance computing hardware and associated progress in computational algorithms has been accompanied by orders of magnitude increases in the volume of generated data. In parallel, the volume of experimental data is also expected to increase considerably, as U.S. scientists have started collaborations on a new generation of overseas long-pulse superconducting fusion experiments. Accordingly, a critical need exists for developing data analysis tools addressing big data challenges associated with computational and experimental research in fusion energy science.

Grant applications are sought to develop simulation and data analysis tools for magnetic fusion energy science addressing some of the challenges described above. Areas of interest include: (1) verification and validation tools, including efficient methods for facilitating comparison of simulation results with experimental data; (2) methodologies for building highly configurable and modular scientific codes and flexible user-friendly interfaces; (3) technologies for managing and analyzing large volumes of complex scientific data; and (4) collaboration tools that enhance the ability of scientists to lead and participate in experimental operations on remote facilities.

The simulation and data analysis tools should be developed using modern software techniques, should be capable of exploiting the potential of current and next generation high performance computational systems, and should be based on high fidelity physics models. The applications submitted in response to this call should have a strong potential for commercialization and should not propose work that is normally funded by program funds. Although applications submitted to this topical area should primarily address the simulation and data analysis needs of magnetic fusion energy science, applications proposing the development of tools and methodologies that have a broader applicability, and hence increased commercialization potential, are encouraged.

Questions – Contact: John Mandrekas, john.mandrekas@science.doe.gov

d. Components and Modeling Support for Validation Platforms for Fusion Science

Small-scale plasma research experiments in the FES program have the long-term performance measure of demonstrating enhanced fundamental understanding of magnetic confinement and improving the basis for future burning plasma experiments. This can be accomplished through investigations and validations of the linkage between prediction and measurement for scientific leverage in testing the theories and scaling the phenomena that are relevant to future burning plasma systems. This research includes investigations in a variety of concepts such as stellarators, spherical tori, and reversed field pinches. Key program issues include initiation and increase of plasma current; dissipation of plasma exhaust power; symmetric-torus confinement prediction; stability, continuity, and profile control of low-aspect-ratio symmetric tori; quasi-symmetric and three-dimensional shaping benefits to toroidal confinement performance; divertor design for three-dimensional magnetic confinement configurations, and the plasma-materials interface. Grant applications are sought for scientific and engineering developments, including computational modeling, in support of current experiments in these research activities, in particular for the small-scale concept exploration experiments. The proposed work should have a strong potential for commercialization. Overall, support of research that can best help deepen the scientific foundations of understanding and improve the tokamak concept is an important focus area for grant applications.

Questions – Contact: Matthew Lanctot , matthew.lanctot@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: Barry Sullivan, barry.sullivan@science.doe.gov

References: Subtopic b:

1. Phillips, C.K., and Wilson, J. R., 2011, Radio Frequency Power in Plasmas: Proceedings of the 19th Topical Conference, AIP Conference Proceedings, Volume 1406, p.1-2, ISBN: 978-0-7354-0978-1. http://scitation.aip.org/content/aip/proceeding/aipcp/1406

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1. Proceedings from the Workshop on Exploratory Topics in Plasma and Fusion Research (EPR2013), 2013, Fort Worth, Texas. http://www.iccworkshops.org/epr2013/proceedings.php

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25. HIGH ENERGY DENSITY PLASMAS AND INERTIAL FUSION ENERGY

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

High-energy-density laboratory plasma (HEDLP) physics is the study of ionized matter at extremely high density and temperature, specifically when matter is heated and compressed to a point that the stored energy in the matter reaches approximately 100 billion Joules per cubic meter (the energy density of a hydrogen molecule). This corresponds to a pressure of approximately 1 million atmospheres or 1 Mbar.

Research in HEDLP forms the scientific foundation for developing scenarios that could facilitate the transition from laboratory inertial confinement fusion (ICF) to inertial fusion energy (IFE). While substantial scientific and technical progress in inertial confinement fusion has been made during the past decade, many of the technologies required for an integrated inertial fusion energy system are still at an early stage of technological maturity. This relative immaturity ensures that commercially viable IFE remains a long-term objective. Research and development activities are sought which address specific technology needs (specified below), necessary to both assess and advance IFE. Given the long-term prospects for IFE, applications submitted under this topical area must also clearly describe their potential/plans for short-term (2-10 years) commercialization in other commercial industries such as telecommunications, biomedical, etc.

Grant applications are sought in the following subtopics:

a. Driver Technologies

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

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

b. Ultrafast Diagnostics

The development of ultrafast diagnostics is needed to assess driver and plasma conditions on sub-picosecond time scales. This technology has the potential to enable the development and deployment of feedback systems capable of ensuring the necessary reliability required for commercially viable IFE. Specific areas of interest include but are not limited to the generation, detection, and control of nonlinear optical processes in plasmas.

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

c. 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.

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

d. 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, 2009, Advancing the Science of High Energy Density Laboratory Plasmas, Report of the High Energy Density Laboratory Plasmas Panel of the Fusion Energy

Sciences Advisory Committee, U.S. Department of Energy, p.184. http://science.energy.gov/~/media/fes/fesac/pdf/2009/Fesac_hed_lp_report.pdf

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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.

26. 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. Metal powder development for Additive Manufacture

Grant application are sought to develop metal powders for use in Binder Jetting, Direct Metal Laser Sintering, or Bound Metal Deposition 3D printers. Many accelerator components must be produced from exotic metals for various beam physics and engineering reasons. Others require less exotic materials like copper. Current production methods utilize machining and welding, and make fabrication of complex geometries difficult, slow, and costly. 3D printing allows complex geometries to be fabricated easily and quickly, but many exotic materials are not available for printing yet. And other metal powders lead to low-density components not of sufficient quality to withstand welding and post-production manufacture. Binder Jetting and Bound Metal Deposition printers offer a relatively low cost of entry into metal 3D printing and use standard Metal Injection Molding (MIM) powders as feed material. Direct Metal Laser Sintering (DMLS) printers cost more and utilize special uniform grain size powders as their feed material. Development of metal powders for any of these 3 printing processes would open 3D printing as an option for the production of complex accelerator components. Proposals submitted to this topic should be directed towards the development of powders used for specific accelerator components such that those components meet the required performance standards. This topic does not include the development of powders for superconducting accelerator components.

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

b. Improved Accelerator Modeling and Control System Software

Grant applications are sought to develop new or improved computational tools for the design, study or operation of charged-particle-beam optical systems, accelerator systems, or accelerator components. These tools should incorporate innovative graphical user interfaces, and tools to translate between

standard formats of accelerator lattice description. Grant applications also are sought for the upgrade of existing codes to incorporate these interfaces (provided that existing copyrights are protected and that applications include the authors' statements of permission where appropriate). The integration of existing application codes into an overall framework is of particular interest.
With regard to accelerator operations, there is a particular need to optimize and modernize existing control systems. Effective use of improved, rapid online models, together with machine learning techniques is encouraged. Grant applications are sought to develop innovative graphical user interfaces that facilitate the design of new or improved control algorithms through effective combination of beam diagnostics, online models, integrated high-fidelity off-line simulation codes, and machine learning techniques. Novel control schemes for high-intensity rapid cycling synchrotrons are required in order to optimize injection, capture, and acceleration. Effective use of existing facilities for testing and proof-of-principle experiments is encouraged.

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

c. High Gradient Accelerator Research and Development

Grant applications are sought to develop an integrated framework to facilitate accelerator modeling in the simulation workflow of the ACE3P code suite. A graphic user interface (GUI) has recently been developed for ACE3P, which has simplified significantly the setup of an application and job submission to remote high-performance computing (HPC) resources. However, ACE3P uses several advanced tools and toolkits in its pre-processor and post-processor for defining geometric models, generating meshes, data analysis and visualization. Integrating these tools and toolkits into the existing GUI to make a standalone framework will allow end users to work with a single software package without the need to manage their own computation resources. Simulation at conventional HPC centers such as NERSC and cloud-based platforms provides different capabilities and benefits with respect to the scientific and industrial communities. Each has its own unique set of configuration requirements and means of managing the computation workflow of a simulation. The resulting framework should be able to interface to both types of computational services from the same application and provide similar process management capabilities. [1]

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

d. High-Current Cathodes

Grant applications are sought for novel design and development of high current cathode using field-emission or other non-laser-based technology for use inside an SRF cavity. Ideas for high average current (> 0.3 A), long life time and inexpensive electron sources for SRF industrial linacs providing high-quality beams are sought. [2]

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

e. High-Emissivity Coating for Targets

Grant applications are sought for high emissivity coatings (or surface treatment) for refractory metals such as tungsten exposed to ionizing radiation and operating in a high to moderate (10^{-5} torr) vacuum environment and at temperatures between 1,000 and 2,000 C. The goal of the high emissivity coating is to improve the radiation heat transfer and lower the operating temperature of targets exposed to a high energy proton beam. The coating must survive the effects of intense ionizing and displacive radiation, in addition to being resistant to oxidation from residual gas in the vacuum environment. [3, 4]

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

f. Non-Linear Magnets for High Dynamic Aperture Lattices

Grant applications are sought for non-linear magnets for high dynamic aperture lattices. Beam intensity limitations in modern particle accelerators are often dominated by the acceptance and/or dynamic aperture of linear beam optics lattices. Recently, a solution for bounded non-linear motion has been suggested that utilizes specially designed magnetic inserts, resulting in a so-called Integrable Optics (IO) beamline, which can support much larger beam currents than an equivalent linear lattice. It was shown that an IO magnetic lattice could be used to design an integrable Rapid Cycling Synchrotron (iRCS) with a much higher current than existing synchrotrons. [5]

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

g. Novel Beam Optics for High-Intensity Hadron Synchrotrons

Grant applications are sought for the development of new concepts in beam optics and lattice design for the efficient acceleration of high-intensity hadron beams in synchrotrons with beam losses of less than 1 W/m. Topics of interest include: (1) Concepts for high-intensity, rapid cycling synchrotrons; (2) Space-charge mitigation techniques; (3) Nonlinear integrable optics and related concepts; and (4) circular optics techniques. Approaches that make use of electron lenses, including high-fidelity modeling of electron lens performance, are of particular interest. Effective use of existing facilities for proof-of-principle experiments is encouraged. [6,7]

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

h. Other

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

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

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27. 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. Vacuum-tube based sources should be designed to operate at <100kV beam voltage to improve reliability and reduce cost of required HV systems. 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. 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.

Radiofrequency power sources of particular interest include:

- The magnetron, provided it is adapted to include control of output power by, e.g., using a grid, and stable phase control by introducing, e.g., injection locking;
- The Klystron, provided it is adapted to significantly increase power efficiency and reduce cost;
- Solid state power amplifiers, provided the high cost per watt can be significantly reduced.

Applications must clearly articulate how the proposed technology will meet all metrics listed in this section.

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

b. High Efficiency High Average Power RF Sources

Future high power accelerators will require highly efficient sources of megawatt-class radiofrequency power. R&D to significantly improve the power efficiency of high-average-power (CW or high duty factor) radiofrequency tubes is sought. Net tube power efficiency (including focusing magnet power) must exceed 80%, and average tube power must exceed 100 kW, with a pulse format (peak power, pulse length) that is appropriate for either normal conducting or superconducting accelerators, and an output that is stably phase locked to an external reference. The proposed device must provide an economical route to producing 1 MW or more of average power by scaling, coherent combination, or both. 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.

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

c. Other

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

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

28. LASER TECHNOLOGY R&D FOR ACCELERATORS

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

Lasers are used or proposed for use in many areas of accelerator applications: as drivers for novel accelerator concepts for future colliders; in the generation, manipulation, and x-ray seeding of electron beams; in the generation of electromagnetic radiation ranging from THz to gamma rays; and in the generation of neutron, proton, and light ion beams. In many cases ultrafast lasers with pulse lengths well below a picosecond are required, with excellent stability, reliability, and beam quality. With applications demanding ever higher fluxes of particles and radiation, the driving laser technology must also increase in repetition rate—and hence average power—to meet the demand. Please note that proposals submitted in this topic should clearly articulate the relevance of the proposed R&D to HEP's mission.

This topic area is aimed at developing technologies for ultrafast lasers capable of high average power (kilowatt-class) operating at the high electrical-to-optical efficiency (>20%) needed for advanced accelerator applications.

Accelerator applications of ultrafast lasers call for one of the following four basic specifications:

	Type I	Type II	Type III	Type IV
Wavelength (micron)	1.5-2.0	0.8-2.0	2.0-5.0	2.0-10.0
Pulse Energy	3 microJ	3 J	0.03–1 J	300 J
Pulse Length	300 fs	30–100 fs	50 fs	100–500 fs
Repetition Rate	1–1300 MHz	1 kHz	1 MHz	100 Hz
Average Power	Up to 3 kW	3 kW	3 kW and up	30 kW
Energy Stability	<1 %	<0.1%	<1%	<1%
Beam Quality	M^2<1.1	Strehl>0.95	M^2<1.1	M^2<1.1
Wall-plug Efficiency	>30%	>20%	>20%	>20%
Pre-Pulse Contrast	N/A	>10^{-9}	N/A	>10^{-9}
CEP-capable	Required	N/A	Required	N/A
Optical Phase Noise	<5°	N/A	<5°	N/A
Wavelength Tunability Range	0.1%	0.1%	10%	0.1%

Grant applications are sought to develop lasers and laser technologies for accelerator applications only in the following specific areas:

a. Cost Reduction of Ultrafast Fiber Laser Components

One route to achieving high peak and average power is to coherently combine the output of many (e.g. thousands of) ultrafast fiber lasers. In this case, power efficiency, beam quality, compactness, reliability, stability, and low cost of the individual lasers are each essential. Note that components and subsystems must be developed for propagating and amplifying high-quality (M2<1.2) ultrafast (<100 fs) laser pulses. Proposals that develop integrated subsystems (e.g. a single-channel fiber amplifier chain) will be given highest priority, although proposals for individual components that offer revolutionary gains in any of the performance characteristics above, and/or in the cost per channel will also be welcomed. While Yb:fiber components are highest priority, Tm:fiber components are also encouraged.

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

b. Novel, Scalable Techniques for Carrier-Envelope Phase Locking of Multiple Fiber Lasers

Combining many fiber lasers coherently for accelerator applications will require stable locking of 10s to 100s of fiber amplifier channels to within a small fraction of an optical period. Proposals to develop a low-noise carrier envelope phase (CEP) technology that is robust, low-cost, and applicable to large numbers of fiber lasers is sought. Novel architectures employing either continuum generation or direct comb generation by optical parametric oscillator techniques to enable low-noise f-2f locking are sought.

Proposed systems must not contain any free-space optics, and priority will be given to highly integrated solutions that minimize the number of fiber connections required. Locking system must demonstrate a CEP locking performance better than 45 degrees RMS of optical phase, and a credible technology path must exist to economically achieving less than 5 degrees RMS locking performance, when measured between any two stabilized fiber lasers. Systems suitable for use at 10 kHz – 100 MHz repetition rates and any near-IR fiber laser type (Yb, Er, or Tm) are sought.

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

c. Ceramic-Based Optical Materials

To achieve high average power and high peak power will require new gain materials with superior damage threshold, dopant density, optical bandwidth, and thermal properties. Sintered laser gain materials for ultrafast lasers offer promise of achieving many of these characteristics. Candidate materials must achieve broad bandwidth (>10%), high peak power (>10 TW), and endure sustained high average power (>kW) operation. Proposals to develop new laser gain materials and/or advanced sintering techniques for producing very high quality laser gain media with large apertures (e.g. greater than 4 cm dia) are sought. The successful proposal will include optical characterization of finished ceramic samples to demonstrate the optical qualities of the sample, including measurements of spectral absorption, transparency (scattering), and accuracy of the doping profile. A demonstration of lasing of the sample ceramic material (over a small aperture) is highly preferred.

Proposals to develop techniques capable of producing precisely controlled spatial gain profiles are strongly encouraged.

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

d. 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/cm^2 at 1 ps or >10 J/cm^2 at 1 ns). 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

e. Computer Modeling Based Development of High Power Coatings for Ultrafast Optics

An identified common bottleneck for all high average and high peak power lasers for accelerator applications is the damage threshold of coatings. Particular interest is in coatings suitable for high power femtosecond-class pulses. Designing robust optics that will survive billions of shots without damage requires the development of predictive modeling of laser damage. Accurate physics-based predictive simulation tools must be developed that provide insight into the mechanisms for laser induced damage, allow strategies to be developed to increase the damage threshold. These predictions must be informed by experiments to test new coatings.

Proposals are sought for R&D that combines both rigorous simulation efforts and state-of-the-art fabrication and testing of new coatings. Simulations must incorporate current best practices in electromagnetic wave theory modeling, the current understanding of laser-induced damage phenomenology, and result in practical coating designs that are then fabricated and tested to validate the model and new approaches to designing high damage threshold coatings. Proposals focusing on only one element (e.g. just simulations, or just coating testing) will be administratively declined as unresponsive.

The goal is a scientific understanding of how to produce coatings specifically for femtosecond-class lasers which support 10% minimum bandwidth operation with very low dispersion, very low absorption loss (consistent with minimal thermally-induced wavefront distortion at incident average power densities of 100 W/cm^2), and high laser damage threshold (0.5 J/cm^2 minimum at 1 ps pulse width). Coating techniques must be scalable to large apertures (e.g., 10 cm x 10 cm) and coatings should be cleanable in the field by standard techniques. Wavelengths of interest are primarily in the near-IR from 0.8 microns to 2 microns, but advances in broadband high damage threshold coatings for use at 9-10 microns are also of interest.

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

f. High Efficiency Spatial Mode Shaping and Control for High Power Ultrafast Lasers

Research on the development of laser plasma accelerators has identified laser transverse model shaping and control, to ensure high efficiency guiding in plasma channels, as one of the key challenges.

Grant proposals are sought to develop fully passive (i.e. using no adaptive optics) methods for producing high Strehl-ratio (>0.95) Gaussian-like far-field profiles from flat-top near-field profiles, for lasers in the femtosecond-class with tens of Joules of pulse energy. Simplicity, robustness, and cost are key considerations of such a mode shaping system. Interest is primarily for ultrashort pulse (<100 fs) very high peak power (>50 TW) Ti:Sapphire systems, but mode shapers suitable for ultrafast high energy Tm lasers are also of interest.

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

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29. SUPERCONDUCTOR TECHNOLOGIES FOR PARTICLE ACCELERATORS

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

Superconducting materials are widely used in particle accelerators to create large continuous electric and magnetic fields for beam acceleration and manipulation. Advanced R&D is needed in support of this research in high-field superconductor, superconducting magnet, and superconducting RF technologies. This topic addresses only those superconducting magnet development technologies that support accelerators, storage rings, and charged particle beam transport systems, and only those superconducting wire technologies that support long strand lengths suitable for winding magnets without splices. 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: 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 new or 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. Primary conductors of 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; new architectures or processing methods that significantly lower the cost of Nb_3Sn wire may also be of interest. Other materials may be considered if high field performance, length, and cost equivalent to these primary materials can be demonstrated. All grant applications must result in wire technology that will be acceptable for accelerator magnets, including not only the operating conditions mentioned above, but also production of a sufficient amount of material (1 km minimum continuous length) for winding and testing cables and subscale coils.

New or improved wire technologies must demonstrate at least one of the following criteria in comparison to present art: (1) property improvement, such as higher current density or higher operating field; (2) improved tolerance to property degradation as a function of applied strain; (3) reduced transverse dimensions of the superconducting filaments (sometimes called the effective filament diameter), in particular to less than 30 micrometers at 1 mm wire diameter, with minimal concurrent reduction of the thermal conductivity of the stabilizer or strand critical current density; (4) innovative geometry for ReBCO materials that leads to lower magnet inductance (cables) and lower losses under changing transverse magnetic fields; (5) correction of specific processing flaws (not general improvements in processing), to achieve properties in wires of more than 1 km length that are presently restricted to wire lengths of 100 m or less; (6) significant cost reduction for equal performance in all regards, especially current density and length.

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

b. Superconducting Magnet Technology

Grant applications are sought to develop: (1) very high field (20 T and above) dipole magnets; (2) designs and prototypes for HTS/LTS hybrid solenoid systems capable of achieving 30 to 40T axial fields and warm bores with a diameter ≥2 cm, which are of interest for final cooling of a muon beam prior to acceleration and injection into a collider storage ring, but also have broader application; (3) alternative designs – to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets – that may be more compatible with the more fragile Nb_3Sn and HTS/high-field superconductors; (4) fast cycling HTS magnets capable of operation at or above 4T/s; (5) reduction in magnetization induced harmonics in HTS magnets; (6) improved magnet designs and industrial fabrication methods for magnets, such as welding and forming, that lead to lower costs; (7) quench protection in HTS magnets and HTS/LTS hybrid magnets.

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

c. Superconducting RF Cavities

Grant applications are sought to develop:

(1) new SRF cavity designs with reduced RF frequency sensitivity to the Lorentz-force detuning and helium bath pressure fluctuations. (2) New SRF cavity designs for operation with high current beams. The cavity should provide efficient high-order mode extraction while not sacrificing good SRF performance. The goal of the new designs is to achieve higher-order mode loaded quality factors in the $10^2 – 10^3$ range for circular accelerators and $10^3 – 10^4$ range for linacs. (3) New fabrication and processing techniques for niobium cavities to reduce the cost and improve quality factor and accelerating gradient (e.g., improved welding technique, hydro-forming, doping, etc.) along with new materials for SRF cavity manufacturing. RF components for SRF cavities. A particular application of interest is for industrial accelerators (operating at RF frequencies of e.g. 650 MHz) in order to provide low cost, reliability and long-term stable operation. (4) New cost-efficient and improved reliability designs of high-power input couplers in the frequency range of 325 MHz to 1.3 GHz. (5) New cryo-module designs with improved static heat losses, mechanical stability and low cost. In particularly, the designs should incorporate features that ensure safe transportation of the cryomodules from an assembly facility to the final location. (6) High-quality low and medium-power RF components for SRF cavity tests (directional couplers, circulators, etc.) and cavity tuners including fast tuners providing wide tuner range (10^{-3}). (7) SRF cryomodule diagnostics that aid in preserving the high performance achieved by SRF cavities during vertical tests throughout the SRF cryomodule assembly, commissioning and operation. (8) New and improved methods for cavity diagnostics in a cryomodule that would aid to preserving the high performance achieved by SRF cavities during vertical tests throughout the SRF cryomodule assembly, commissioning and operation, including in situ Q_0 measurements inexpensive sensors for residual magnetic field measurements at cryogenic temperatures, novel sensors for helium pressure, flow, and level based on fiber optics or other technologies, vibration sensors in a cryogenic environment, distributed radiation and dark current/field emission sensors using fiber optics at cryogenic temperatures. (9) Algorithms and electronics for resonance control of the narrow-band cavities to counteract Lorentz-force detuning and microphonic noise. (10) In situ cleaning of SRF cavities inside the cryomodule, to mitigate field emission on both niobium and Nb_3Sn cavities. Plasma cleaning is of interest since it is already proven to be effective as an in-situ technique of cleaning the cavity surface from organic contaminants. Methods to improve the plasma cleaning technique to remove field emitters of different

nature, as for example metallic flakes, are of interest. Techniques capable to mitigate field emission in-situ in the cryomodules are needed to ensure high accelerating gradients in modern and future machines.

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

d. Cryogenic and Refrigeration Technology Systems

Grant applications are sought for (1) high thermal conductivity materials (better than 10^4 W/K·m at 4 K) for use in cryogenic environments; (2) the development of wireless or serial optical technologies for thermal, voltage, and pressure measurements in cryogenic environments; (3) the development of thermally efficient conduction cooled power leads for superconducting magnets through the use of good thermal intercepts which also electrically isolate. This would benefit all applications of superconducting magnets and LINACS. (4) The development of simple, robust, high power (≥10 W at 4 K) cryo-coolers to enable stand-alone SRF cavity and SC magnet applications for HEP and Industry.

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

e. Other

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

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

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30. HIGH-SPEED ELECTRONIC INSTRUMENTATION FOR DATA ACQUISITION AND PROCESSING

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, processing, storage, distribution, and analysis of experimental data. 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 those planned for the High Luminosity (HL) upgrade of the Large Hadron Collider (LHC; see www.cern.ch) or potential future High Energy Colliders, neutrino experiments including those sited deep underground (e.g., 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 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.

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

b. Engineered Substrates for Particle Detectors at High Energy Colliders

Low to moderate gain (x10-50) reach-through silicon avalanche diodes (LGADs) are 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

c. Technology for Post-Processing of Junctions for CMOS and CCD Sensors

Monolithic Complementary Metal Oxide Semiconductor (CMOS) Sensors have the potential to provide reduced noise, improved radiation hardness, and reduced cost compared to hybrid sensors for elementary particle physics detectors. Several foundries provide CMOS technology that is compatible with sensor integration. A similar situation exists for Charge-Coupled Devices (CCDs), which are used in astrophysics and direct dark matter detection. The optimum sensors are fully depleted high resistivity devices, which require a backside junction. Many applications also demand a very thin entrance window junction. The foundry processes, however, do not provide double sided processing. Adding the junction after the CMOS processing has been completed is problematic, because the temperature necessary to activate the dopant would damage the CMOS or CCD structure on the front side. Proposals are sought for novel, robust, cost-effective process technologies to enable backside junction activation at temperatures below 400 C, and that are compatible with post-foundry substrates and both CCD and CMOS sensors. MBE and laser anneal technologies are specifically excluded from this call.

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

d. Specialty Wafers and Thick Sensors for HEP Dark Matter Detectors

Proposals are sought for technologies to support production of active bulk rare event semiconductor detectors. Materials include very high crystal quality silicon, germanium, gallium arsenide and possibly others. Present devices are based on silicon or germanium with either Charge-Coupled-Devices (CCDs), CMOS imagers, or micro-calorimeter sensing elements. For silicon, direct wafer bonding technologies have the potential to increase sensitive detector mass by attaching additional layers of active material and build up ~5mm thick sensors with active electronics on the surface. Proposed work may include bonding of existing silicon structures to additional layers of high resistivity material and demonstration of high charge collection efficiency. For germanium we are interested in production of high quality wafers in 6" diameter, as well as processing methods and capabilities for complex electronic circuitry on germanium. For gallium arsenide we are interested in high purity material and precision doping methods. Relevant technologies needed for processing above materials include fine feature (sub-micron) lithography on non-standard size elements, such as thick wafers (typically 6" diameter) and non-wafer shapes, such as cubes of 1cm or more on a side.

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

e. High Density Chip Interconnect Technology

The demands on silicon particle tracking detectors in terms of pixel size, mass budget, data rate, and front-end processing are increasing. 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.

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

f. 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, 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; free-space/Visible Light Communication (VLC) is also of interest.

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.

VLC systems should have bandwidth approaching 10Gbps, produced from radiation-hard, commercially available components and with high reliability and low cost.

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

g. Custom Real Time Massively Parallel Trigger Processors for Detectors at High Energy Colliders

Many next-generation scientific experiments will be characterized by huge quantities of data, taken at high rates, from which scientists will have to unravel the underlying physical processes. In most cases, large backgrounds will overwhelm the physics signal of interest. Since the quantity of data that can be stored for later analysis is limited, real-time event selection is imperative to retain interesting events while rejecting background signals.

As an example, at one end of the scale one of the four modules of the DUNE neutrino detector will have to examine about 0.25 Tera-bits per second of data and be able, within about 1 milli-second, to reject background clutter by a factor of order 1 million. At the other end of the scale an upgraded LHC tracking detector must deal with more than one hundred times as much data and reject uninteresting data within a few micro-seconds but with rather lower rejection factors of order 1,000 to 10,000.

Current technology can just barely be scaled to the DUNE case and cannot be scaled to the LHC case, so significant improvements or breakthroughs will be needed for these and other next-generation scientific experiments. Proposals are sought for new technology to significantly improve real time high speed, low latency, data communications as well as state of the art fast pattern recognition capability. Examples include (but are not limited to) board or module designs with extremely high speed interface capability, PCB design technologies that are compatible with next-generation 100G full-mesh backplane or beyond, technology to integrate modern FPGAs, GPUs or ANNs with such high speed interface capability, application tools or methods to improve the ability or ease of use of commercial FPGAs, GPUs or ANNs to rapidly separate interesting event features from uninteresting data, and/or custom ASIC chips dedicated for fast pattern recognition such as content addressable memory or other novel pattern recognition engines.

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

h. Frequency Multiplexed DAQ Systems Motivated by Cosmic Microwave Background Detectors

Future CMB experiments will have large focal plane arrays with ~500k superconducting detector elements for optical, near-IR, millimeter and microwave astronomical surveys.

Grant applications are sought for the development of data acquisition systems for these arrays and for detectors needing similar systems. Areas of development include low-noise cryogenic amplifiers (HEMT, SQUID, Parametric, etc.), high-density cryogenic interconnects, high-frequency superconducting flex circuits, and specialized electronics for processing large numbers of frequency domain multiplexed RF signals.

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

i. 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, to digitize waveforms at above 10Gs/s. 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 or sub-ps sensitivity and stability are of immediate interest.

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

j. 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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3. 21th International Conference on Computing in High Energy and Nuclear Physics (CHEP), 2015, Okinawa, Japan. https://indico.cern.ch/event/304944/

4. 13th Pisa Meeting on Advanced Detectors, 2015, La Biodola, Isola d'Elba, Italy. https://indico.cern.ch/event/359839/

5. International Conference on Technology and Instrumentation in Particle Physics 2017 (TIPP2017), 2017, Beijing, China. http://tipp2017.ihep.ac.cn/

6. 19th Real-Time Conference, 2014, Nara, Japan. http://rt2014.rcnp.osaka-u.ac.jp/

7. 14th Vienna Conference on Instrumentation (IAEA), 2016, Vienna, Austria. https://vci2016.hephy.at/home/

31. 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 those planned for the High Luminosity (HL) upgrade of the Large Hadron Collider (LHC; see www.cern.ch) or potential future High Energy Colliders, neutrino experiments including those sited deep underground (e.g., www.dunescience.org), next generation direct searches for dark matter, and astrophysical surveys to understand cosmic acceleration, 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. Lower Cost, Higher Performance Visible/(V)UV Photon Detection

Detectors for particle physics need to cover large areas with highly sensitive photodetectors. Experiments require combinations of the following properties: 1) Large photosensitive area, compatible with cryogenic and/or high pressure operation, and built with low-radioactivity materials for neutrino and dark matter detectors; 2) Fast response, radiation hardness, magnetic field compatibility, and high quantum efficiency for LHC and intensity frontier experiments; and 3) Low cost and high reliability.

Technologies using modern manufacturing processes and low cost materials are of interest. These include use of semiconductor-based avalanche photodiodes (APD) and Geiger mode APD arrays, SiPM arrays, large area microchannel plate-based systems, new alkali and non-alkali photocathode materials, and high volume manufacturing of large-area, ultra clean, sealed vacuum assemblies.

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

b. Technology for Large Cryogenic Detectors

Liquid noble gas detectors are in use and under development for dark matter and neutrino experiments and in the latter case on a very large scale – for example, as large as 10 kton modules of liquid argon for the DUNE experiment. These large scale cryogenic detectors at DOE and in the wider HEP community require significant technological advances.

Electrical feedthroughs through cryostat walls are needed for low voltage power (1 to 10 V, a few Amperes), high speed differential signals (up to 3 Gb/s), low frequency and voltage monitoring and control signals, and High Voltage (up to 600kV) low current DC bias supplies. A typical case might require order one thousand low voltage power, signal and control wires penetrating the cryostat wall at one location, while HV connections would likely have dedicated feedthroughs. These penetrations need to be area-efficient, minimize cold leaks, and control contamination. Feedthroughs are generally warm (i.e., the interior cable enters the cryostat in the gas rather than liquid phase) but in some instances cold feedthroughs (i.e., entry directly into the liquid) are required or would be advantageous. In such cases the pressure head could reach 3 atmospheres.

Purification materials and filtration systems for efficient operation of high purity multi-kiloton cryogenic noble liquid systems are needed. Filtration systems or methods that can efficiently remove trace amounts of Oxygen and Nitrogen are needed for all detectors.

Present commercial chip packaging and mounting technologies can, at cryogenic temperatures, put mechanical stress on the silicon die which distort the operation of the circuit. Low cost and robust packaging and / or interconnect solutions that did not introduce such stresses would be of advantage – especially in the case of large area circuit boards (> 0.5 m on each edge).

Methods of ensuring planarity and flatness at the few mm level for tiled arrays of circuit boards covering areas of up to 12 m x 60 m while allowing for cable routing on the reverse side of those boards are needed.

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

c. Cryogenic Bolometer Array Technologies

Future Cosmic Microwave Background experiments and QIS applications will require scalable high-fidelity superconducting circuits. Novel fabrication processes are needed to enable large-scale detector arrays with associated highly multiplexed readout. The development of scalable high density superconducting interconnects for micro-fabricated superconducting devices is also of interest. Development of sub-kelvin (10-100mK base temperature) cryogenic systems suited for operation of large arrays with large operational cryogenic volumes, cryogen-free operation, high cooling power with multiple thermal intercepts, closed-cycle and continuous-cycle operations are also of high interest; so are mechanical systems and bearings for operation in vacuum at cryogenic temperature, wafer processing combining niobium metal and MEMS, and fabrication of miniature, ultra-low loss, superconducting resonator arrays.

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

d. Ultra-Low Mass, High-Rate Charged Particle Tracking

High intensity experiments searching for very rare phenomena, such as neutrino-less coherent muon-to-electron conversion and muon decays to e+e-e- or to e- gamma, require precision charged particle tracking at low momenta in the 10 - 100 MeV/c range. Momentum resolutions of 0.1% are required in order to mitigate steeply falling physics backgrounds, necessitating ultra-low mass designs. We seek technologies capable of achieving 10-100 micron position resolution while operating in vacuum and handling average rates from 10 kHz/cm^2 to 1 MHz./cm^2. The mass of these sensors and associated cooling and cabling must correspond to less than 50 microns of silicon per detector layer. Technologies to be considered include gas-filled aluminized mylar tubes with wall thickness less than 10 microns and thinned CMOS sensors. We also seek cooling technologies for CMOS sensors able to extract heat (~50-100 mW) to remote (~1 meter) heat sinks with minimal mass.

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

e. 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 nano-second) scintillators and wavelength shifting materials is of particular interest to the colliding beam community. Development of fast (tens of nano-second), wavelength-matched shifting materials is of interest for liquid argon and liquid xenon detectors for neutrinos and dark matter. Brighter, faster, radiation-hard crystals with high density are of interest for intensity frontier experiments as well as colliding beam experiments.

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

f. Ultra-Low Background Detectors and Materials

Experiments searching for extremely rare events such as nuclear recoils from WIMP dark matter particles or neutrino-less double beta decays require that the detector elements and the surrounding support materials exhibit extremely low levels of radioactivity. The presence of even trace amounts of radioactivity in or near a detector induces unwanted effects. New instruments and techniques are needed and may include: 1) Instruments to measure ultra-low-backgrounds of gamma, neutron and alpha particles; 2) Improvements in the ability to measure and control radon or surface contamination; 3) Development of ultra-radio-pure materials for use in detectors; and 4) Manufacturing methods and characterization of ultra-low- background materials.

Grant applications are sought to develop plastic solids and parts from high purity, low radioactivity polymer raw materials, where the resulting solids and parts preserve the low radioactivity of the original plastic resins or powders. Plastics should have mechanical properties equal to or better than polyvinylidene fluoride (PVD), and ideally comparable to polyetheretherketones, polyaromatic etherketones, polyimides, polyetherimides, and polyamideimides. Many components for ultra-low background radiation detectors, used for detecting rare events in physics, must be made from insulating materials with low radioactivity. Their uses include functions as structural components, or as substrates and parts of electronic assemblies. Conventional methods such as injection molding or extrusion involve intimate contact between molten polymer resins and hot metal surfaces, sometimes with additives present, leading to solids that are significantly more radioactive than the original polymer resins or powders. The radio-contaminants include natural uranium and thorium introduced in dust, radon as a gas and subsequent progeny implanted during radioactive decay, and potassium from human contact and present in many oils and other solutions used in processing. Various 3D printing techniques could significantly reduce or eliminate the introduction of radio-contaminants in the processing from high purity, low radioactivity powders to finished parts.

Grant applications are sought for the development of low-radioactivity liquid scintillator cocktails that avoid high volatility solvents and are not environmental pollutants. One of the most radio-pure liquid scintillators to date was produced by the Borexino experiment, but the solvent is pseudocumene, which has a very low flash point and is a severe marine pollutant. Due to safety concerns, the use of hazardous materials is being either limited or completely eliminated at underground physics laboratories. However, the need still remains, and a direct replacement does not exist commercially. This includes the use of liquid scintillators in active veto detectors, or as the primary detection material. A stretch goal is to reach uranium and thorium levels of approximately 10^{-16} g/g, and the ability to distinguish between gamma and neutron events is highly desirable. For some applications, the scintillator must also be water miscible.

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

g. 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 (>20Wm/K for 0.1g/cc) and stiffness; adhesives with very high thermal conductivity (>4 Wm/K) and radiation tolerance (>100Mrad); low mass composite materials with good electrical properties for shielding, data transmission or power conduction; and radiation tolerant (>100Mrad) low loss dielectric materials. Improvements to manufacturing processes to take advantage of new or recently developed materials. Performance and stability from room temperature to cryogenic temperatures (70K and 4K) are of interest.

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

h. Additive Manufacturing

Detectors for particle physics 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 environments. 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, are of interest to address critical technical challenges in high energy physics. Areas of particular relevance are embedded cooling structures, low-mass support structures and micro-capillary glass arrays.

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

i. 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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32. QUANTUM INFORMATION SCIENCE (QIS) SUPPORTING TECHNOLOGIES

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

Quantum science and instrumentation for next-generation computing, information, and other fields—the core of "quantum information science" (QIS)—are developing rapidly and present numerous opportunities for impacts in high energy physics. Quantum sensors and controls, analog simulation, and qubit systems that specifically rely on or exploit superposition, entanglement, and squeezing of physical states are of particular interest. This topic focuses on key technologies to support quantum information systems that build on experience in high energy physics experimental systems, and on further development of quantum information systems for application in precision measurement, simulation, and computation that advances high energy physics research.

Grant applications are sought in the following subtopics:

a. Development of Optimal SRF Cavity Geometries for Quantum Information Systems

One promising architecture for quantum computing involves superconducting Josephson-junction-based qubits enclosed by superconducting 3D microwave resonators, currently providing the longest coherence times among all superconducting qubits. Achieving the highest possible quality factor Q of the host resonators is one of the identified high impact directions for improving the coherence time of the cavity-qubit systems, as the superconducting resonator serves as a “shield” to isolate the qubit from environmental de-coherence. Furthermore, high-Q cavities have been proposed as possible “quantum memories” where information about the quantum state can be stored during computations. A typical frequency range for superconducting qubit operation is 6 GHz to 15 GHz. 3D niobium SRF cavities, similar to those used in particle accelerators, should be able to provide high quality factors in this frequency range. However, existing cavity geometries are optimized for particle acceleration rather than hosting qubits. Grant proposals are sought for development of 3D SRF cavity geometries in the frequency range of 6 GHz to 15 GHz for hosting superconducting Josephson-junction-based qubits. The geometries should be suitable for scalability from a single SRF cavity-qubit unit to multi-qubit systems.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

b. Optimization of Fabrication Techniques for Scalable 3D SRF Structures for Quantum Information Systems

Traditionally, 3D niobium SRF cavities for particle accelerators are fabricated using electron beam welding of stamped/hydro-formed parts. This approach works well at frequencies below 3.9 GHz. However, future quantum information science (QIS) systems will likely operate in the frequency range of 6 GHz to 15 GHz and will consist of many individual cavity-qubit units coupled together. It is very important to re-assess the cavity fabrication and develop new techniques suitable for high-frequency, scalable SRF structures for QIS. An example of such technique could be precise machining of split-cell-like structures. Grant proposals are sought to develop cavity fabrication techniques optimized for scalable 3D SRF structures for QIS.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

c. Development of Low-Temperature Technologies for QIS Systems

QIS systems operating below one Kelvin (1 K) are growing in scope and cold mass, and potentially include next generation cosmic microwave background (CMB) detectors, dark matter search detectors, some qubit systems for quantum computing, and other quantum sensor technologies operating in the milli-Kelvin (mK) range. Grant proposals are sought for the development of: (1) 4He/3He hybrid refrigeration systems that can efficiently sink power at both 1 K and mK temperatures, likely requiring separating the dilution refrigerator circuit from a separate 1 K cryogenic system; (2) High Density Interconnect (HDI) cables for microwave and RF readouts (frequencies ~1 – 10 GHz) operating with high bandwidth and low thermal loss at mK temperatures that transition to 1 K temperatures; (3) low-power mechanical actuators that can operate at mK temperatures with low thermal loss; (4) low-noise electrical circuit switches operating at mK temperatures with injected noise at the few-quanta noise level; (5) low-noise electronics for excitation and front-end readout of transmon/SRF cavity multi-qubit systems.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

d. Photodetectors for Optical to Microwave Transduction of Quantum Information

Improvements in microwave detection can be applied to cosmic microwave background and axion detection, and may be enabled by QIS-based approaches. While substantial quantum squeezing can be produced optically, the ability to write that information onto microwave photons in a cavity would enhance the readout of microwave detectors. With improvements in transduction of quantum information, entanglement could also be distributed among many distant microwave resonators to create a very large sensor network (using entangled photons). Transduction of the full state would allow for preserving entanglement and other properties from microwaves to optics and back. Many of these features could be achieved with unidirectional transduction. Grant proposals are thus sought for production, testing, and/or validation of photodetector systems with high speed (>5GHz) and high quantum efficiency (>95%) for the purpose of detecting continuous variable quantum information and writing it onto microwave photocurrents that are compatible with microwave cavities. Devices that can coherently transduce a quantum state from photonic to microwave degrees of freedom, or vice versa, are also sought. Unidirectional devices with 50% or more transduction efficiency are desired.

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

e. Other

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

Questions – Contact: Altaf Carim, altaf.carim@science.doe.gov

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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 three priority focus areas:

1. Maintaining the current nuclear reactor fleet;
2. Encouraging growth for a new advanced reactor pipeline (both near- and longer-term), including through the employment of key private-public partnerships; and,
3. Redeveloping America's nuclear fuel cycle, infrastructure, and supply chain.

Nuclear energy is a key element of United States (U.S.) energy independence, energy dominance, electricity grid resiliency, national security, and clean baseload power. America's nuclear energy sector provides over 60 percent of the nation's annual clean electricity production, generates nearly 20 percent of U.S. electricity from a fleet of 99 operating units in 30 states, supports 500,000 jobs, and contributes $60 billion per year to our Gross Domestic Product (GDP). America's nuclear energy sector also plays key national security and global strategic roles for the U.S., including nuclear nonproliferation.

The Office of Nuclear Energy's SBIR/STTR workscopes also support the DOE Gateway for Accelerated Innovation in Nuclear (GAIN) initiative (see https://gain.inl.gov), which provides the nuclear energy community with access to the technical, regulatory, and financial support necessary to move new or advanced nuclear reactor designs toward commercialization while ensuring the continued safe, reliable, and economic operation of the existing nuclear fleet.

33. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

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

New methods and technologies are needed to address key challenges affecting the future deployment of nuclear energy and to preserve U.S. leadership in nuclear science and engineering, while reducing the risk of nuclear proliferation. This topic addresses several key areas that support the development of crosscutting and specific reactor and fuel cycle technologies.

Grant applications are sought in the following subtopics:

a. Advanced Sensors and Instrumentation (Crosscutting Research)

Improvements and advances are needed in the technical area of Advanced Sensors and Instrumentation (ASI) for crosscutting technologies for innovative sensors and measurement technologies to characterize parameters that directly support existing power reactors, materials test reactors, and transient test reactors; innovative digital technology for use in improving monitoring and control of nuclear energy systems; enable the development of advanced power reactor designs; and facilitate development and implementation of advanced fuel cycle technologies.

Technology should demonstrate greater accuracy, reliability, resilience, higher resolution, and ease of replacement/upgrade capability for applications in the nuclear environment and also reduce operations and maintenance costs and address regulatory concerns.

The selected technology should support the Gateway for Accelerated Innovation in Nuclear (GAIN) Initiative and be applicable to multiple reactors or fuel cycle applications, i.e. crosscutting.

Applications are sought in the following areas:

- Develop and demonstrate new sensors and instrumentation for advanced plant control, data analytics, and nuclear applications. Applicants should: develop advanced instrumentation and communication of data located in high temperature, high radiation reactor cores; develop smart multimodal measurement devices to measure unique and complementary parameters simultaneously; develop new or unique application of materials for sensor development that support monitoring, controls, and communications within harsh nuclear reactor environments; develop new radiation resistant sensors for in-core measurement of: local radiation and temperature (e.g. solid-state detectors, diamond thermistors); dimensional changes (specifically diameter and volume) and crack propagation; material properties, such as thermal conductivity, mechanical properties, thermal expansion, etc.); fission gas release (pressure and composition); or other in-core parameters important to reactor safety and/or fuel performance.
- Digital monitoring and control systems that increase nuclear plant system reliability, availability, and resilience including the ability to detect and manage faults in I&C systems and plant components; state of the art control rooms, control systems, and plant control technologies, including automated work management systems; and big data analytics and applications to improve plant operation and control.
- Nuclear Plant Communication technologies that securely and reliably support greater data generation and transmission demands expected to accompany advancements in digital sensor, measurement, and control technologies. This may include power harvesting, energy storage, data transmission techniques, and related methods to reduce both power cabling and communication cabling needed for sensors and communications in I&C systems.
- Development of innovative technology for digital/electronic field support systems for nuclear facilities. These technologies should be integrated and seamless able to enhance current state of the art technology used at nuclear facilities for real time measurements such as: visual inspections and accountability; area radiation monitoring via remote monitoring or as part of personnel dosimetry; access and location monitoring – personnel access and security tracking; or field worker "Head Up Display" to provide design/engineering information

Grant applications that address the following areas are NOT of interest for this subtopic and will be declined: nuclear power plant security, homeland defense or security, or reactor building/containment enhancements; radiation health physics dosimeters (e.g., neutron or gamma detectors), and radiation/contamination monitoring devices; U. S. Nuclear Regulatory Commission probabilistic risk assessments or reactor safety experiments, testing, licensing, and site permit issues.

Questions – Contact: Suibel Schuppner, Suibel.Schuppner@nuclear.energy.gov

For more information on the ASI program visit https://www.energy.gov/ne/nuclear-energy-enabling-technologies

b. Advanced Technologies for the Fabrication, Characterization of Nuclear Reactor Fuel

Improvements and advances are needed for the fabrication, characterization, and examination of nuclear reactor fuel. Advanced technologies are desired for light water reactor fuels and materials, with current emphasis on Accident Tolerant Fuel (ATF) program needs, and for advanced reactor fuels including TRISO particle fuels for Advanced Helium Gas-Cooled Reactors [1, 2, 3, 4, 5, 6, 7] and fuels for sodium and lead fast reactors. Specific technologies that improve the safety, reliability, and performance in normal operation as well as in accident conditions are desired.

- Provide new innovative ATF LWR fuel concepts, to include fuel and/cladding, with a focus on improved performance (especially under accident scenarios), and with a priority on ceramic cladding and novel pellets. Improvements to LWR fuel and cladding may include but not be limited to fabrication techniques or characterization techniques to improve the overall performance or understanding of performance of the nuclear fuel system.
- Develop advanced automated, continuous or batch mode process techniques to improve TRISO-fueled pebble manufacturing to include: (a) improved fabrication methods for isostatic pressing of TRISO pebble bed fuel including both the fueled inner region and unfueled matrix outer rind using advanced automated fabrication to replace manual manufacturing techniques, and (b) advanced methods for non-destructive evaluation testing of TRISO-fueled pebbles.
- Develop improved fabrication methods for fast reactor fuels and cladding materials, especially for uranium based metallic fuel.

Grant applications may use non-fueled surrogate materials to simulate uranium, plutonium, and minor actinide bearing fuel pellets or TRISO particles for demonstration. Actual nuclear fuel fabrication and handling applications which require use of the Nuclear Science User Facilities, the Idaho National Laboratory hot cells and fuel fabrication facilities or the Oak Ridge National Laboratory Advanced Gas Reactor TRISO fuels laboratory facility [6, 7] to demonstrate the techniques and equipment developed may be proposed. Actual nuclear fuel specimen tests may be considered for irradiation in the INL Advanced Test Reactor (ATR) or ORNL High Flux Isotope Reactor (HFIR) but will need to prove technical feasibility prior to insertion into the ATR or HFIR for irradiation testing. Access to the aforementioned facilities is not guaranteed as part of this solicitation and must be obtained through a separate GAIN or SBIR/STTR award.

Grant applications that address the following areas are NOT of interest and will be declined: thorium based fuels, spent fuel separations technologies used in the Fuel Cycle Research and Development Program [5] and applications that seek to develop new glove boxes or sealed enclosure designs.

Questions – Contact: Frank Goldner, Frank.Goldner@nuclear.energy.gov

c. Materials Protection Accounting and Control for Domestic Fuel Cycles

Improvements and advances are needed for the development, design and testing of new sensor materials and measurement techniques for nuclear materials control and accountability including process monitoring that increase accuracy, resolution, and/or radiation hardness, while decreasing intrusiveness on operations and manufacturing costs. Specifically, concepts and integration of safeguards and security features into the design and operation of fuel cycle facilities including: molten salt reactors, electrochemical recycling facilities, other fast reactors are being sought. Grant applications are sought for: (1) Sensors based on radiation detection; (2) New active interrogation methods; (3) Non-radiation based sensors (stimulated Raman, laser-induced breakdown spectroscopy, fluorescence, etc.). Grant applications are also sought for the development of new methods for data validation, data integration, and real time analysis with defense-in-depth and knowledge development of facility state during operation.

Detectors that may indicate unauthorized materials diversion can be equally useful in identifying system upsets and the need for process control changes. Grant applications are sought for the development of dual-use as well as single purpose instruments and detectors.

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 is critical for their design and operation. Nuclear engineering simulations are 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:

- Facilitate access to Office of Nuclear Energy's (NE) advanced modeling and simulation tools (https://gain.inl.gov/SitePages/ModSim.aspx) for inexperienced users, such as automated generation of finite element meshes, especially hexahedra meshes (and in particular we seek automated mesh generators that leverage tet-to-hex and other hybrid-to-hex algorithms to produce high-quality high-order fully hexahedral meshes) from CAD or combinatorial solid geometry models;
- Demonstrate an effective approach for providing training on these NE tools to new and experienced 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.

Questions – Contact: David Henderson, David.Henderson@nuclear.energy.gov

e. Plant Modernization

Improvements and advancements are needed to address nuclear power plant economic viability in current and future energy markets through innovation, efficiency gains, and business model transformation. This includes transformative digital technologies that results in broad innovation and business process improvement in the nuclear light water reactor fleet's operating model. The modernization of plant systems and processes will enable a technology-centric business model platform that supports improved performance at lower cost, contributing to the long term sustainability of the LWR fleet, which is vital to the nation's energy and environmental security.

Technology should demonstrate and support improved functionality and efficiencies in plant operation and maintenance processes. This will include improvements for both core operations and maintenance work activities, as well as support functions, such as security, management, administration, procurement, and radiation protection. Effective modernization requires improved process automation, machine intelligence and computer aided decision making. To achieve this mission in the nuclear power industry, applications are sought in one of the following plant modernization areas:

- I&C modernization: Technologies are sought to reduce the burden of modernizing the I&C infrastructure through novel methods to automate or streamline the I&C equipment replacement, function sustainability, integration, installation, and testing. In addition, technologies are sought to overcome collateral issues that arise during an I&C modernization. These solutions would address both costs and applicable regulatory concerns.
- Data use: Technologies are sought for novel sensors, devices, and methods to extract data from nuclear power plants to automate current operations and maintenance activities. The purpose of the data extracted should be to enhance the online monitoring of nuclear power plants. The technologies sought should have direct value of deployment.
- Advanced Applications: Technologies are sought to facilitate the use of tools and products that are available in other industries, yet face obstacles and challenges to be utilized by the nuclear power industry. Examples of the sought technologies are intelligent tools to automate the conversion of work packages to electronic work packages with minimal human involvement, smart scheduling technologies that recognizes patterns and provide a machine-intelligent scheduling functions for nuclear power plants.

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

f. Materials R&D

Welding is widely used for repair, maintenance, and upgrade of nuclear components. Weld repairs are a potential method for mitigating cracking or degradation instead of component replacement. These repair welds need to have improved resistance to stress corrosion cracking and to other long-term degradation. Furthermore, new and improved welding techniques are needed to avoid and/or reduce any deleterious effects associated with the traditional welding fabrication practices particularly associated with helium induced cracking of irradiated materials. The DOE Light Water Reactor Sustainability Program has been working in collaboration with the Electric Power Research Institute to develop and assess the ability of friction stir welding (including friction stir cladding) and advanced laser welding techniques to be used for highly irradiated materials. This call seeks proposals that would develop the means for deploying this technology to reactor component repair. Phase I seeks to provide a feasibility study, supportive research for weld systems if used in underwater conditions, and initial design study for a system of deployment, with later Phase II work developing and demonstrating the prototype system using a scale mock-up of potential reactor areas where weld repair would likely be needed.

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

g. Component Development for Energy Conversion Systems to Support Nuclear Power Systems

Molten Salt Reactors (MSR) represent a potential revolutionary shift in the implementation of nuclear power, and as a broad class of reactors, have the potential to directly address many US objectives. As high temperature reactors, they offer increased power conversion efficiency, high temperature process heat, reduced waste heat rejection, the possibility of dry heat rejection, and increased fissile resource utilization. MSRs can be deployed at gigawatt-scale or as small modular reactors. This flexibility, along with improved heat rejection characteristics, greatly expands siting opportunities for MSRs. Low-pressure operation with chemically inert coolants allows for thinner walled components that may be significantly less expensive. Many major plant components could potentially be replaceable. The ability to continually process fission products out of the reactor system changes the nature of accident scenarios and could allow for important innovations such as passive, walk-away safety and a meaningful reduction of site emergency planning zones. MSRs are versatile and powerful machines and can assist in closing the fuel cycle by reuse of fuel and by consumption of surplus fissile inventories.

DOE is seeking proposals for collaborative small business partnerships from a U.S. company or companies to advance Molten Salt Reactors and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Development of a small electromagnetic fuel salt pump to support either side stream processing or small experimental loops.
- Development of multi-use fuel salt flange connection suitable for connection/disconnection with remote tooling.
- Demonstration of a flexible/bellows coupling for molten salt lines to enable seismic separation of plant systems.
- 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

h. Advanced Methods for Manufacturing

A strong manufacturing base is essential to the success of the U.S. reactor designs currently competing in global markets. In addition, the success of the Small Modular Reactor (SMR) Initiative depends heavily on the ability of the U.S. to deliver on the SMR's expected advantages – the capability to manufacture them in a factory setting, dramatically reducing the need for costly on-site construction – thereby enabling these smaller designs to be economically competitive. This workscope also supports the Department of Energy's Gateway for Accelerated Innovation in Nuclear (GAIN) initiative which provides the nuclear community with access to the technical, regulatory, and financial support necessary to move new or advanced nuclear reactor designs toward commercialization. The initiative also helps to ensure the continued safe, reliable, and economic operation of the existing nuclear fleet.

Applications are sought in the following area:
Advanced fabrication and manufacturing methods will require advances in welding processes and inspection methods that can maintain production speed and efficiency with the manufacturing processes. Component manufacturing technologies will be required that take full advantage of the new 3-D printing methods employed by additive manufacturing technologies. These manufacturing methods must be capable of producing components or sub components on a limited production basis and with nuclear quality.

Grant applications are sought for:

- Methods to improve the process, speed, quality and cost of welding and the required in-process and post welding inspections
- Methods that can improve the manufacturing processes required for the development of pressure vessels for a TREAT irradiation vehicle using Inconel-718 through additive manufacturing process that meets ASME requirements. If required, heat treatment process specifications should be developed and associated mechanical properties data produced to allow for production and use of the component for applications meeting ASME pressure boundary requirements.

Questions – Contact: Tansel Selekler, Tansel.Selekler@nuclear.energy.gov

i. Cybersecurity Technologies for Protection of Nuclear Safety, Security, or Emergency

The U.S. Department of Energy Office of Nuclear Energy is seeking science and engineering solutions that provide nuclear operators with tools to prevent, detect, and mitigate cyber threats to nuclear energy systems while operators increase the utilization of cost-effective digital instrumentation, control, and communication systems. Proposals of interest will address research in technology products that can enable system designers and operators to model or characterize the cybersecurity behaviors and effectiveness of instrumentation and control (I&C) components and systems that are used within nuclear facilities. Models should capture the behavior of an I&C system to: 1) simulate the characteristics of an I&C system under cyber-attack; 2) study the cyber risk impacts of upgrades and maintenance on such systems; and/or 3) facilitate nuclear facility operation cybersecurity education and training.

Proposals are also sought for exploring secure digital I&C system architectures for use in nuclear facilities. These architectures should minimize common cause cybersecurity failures and common access attacks; eliminate various classes of cyber attacks, including cyber attacks that are enabled through the supply chain; and/or enhance capability to be resilient to a cyber attack if a system has been infiltrated.

Questions – Contact: Trevor Cook, Trevor.Cook@nuclear.energy.gov

j. 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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34. ADVANCED TECHNOLOGIES FOR NUCLEAR WASTE

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

The US DOE Office of Nuclear Energy, Office of Spent Fuel and Waste Science and Technology is conducting research in long-term storage, transportation, and eventual disposal of spent nuclear fuel (SNF). Storage of SNF is occurring for longer periods than initially intended; therefore, it is desirable to assess technical performance issues of the SNF storage systems and transportation systems after extended durations. In the area of SNF disposal, research is directed toward generic repository disposal systems in argillite, salt, and crystalline rock.

Grant applications are sought only in the following subtopics:

a. Spent Fuel and Waste Science and Technology, Disposal R&D

Assessments of nuclear waste disposal options start with waste package failure and waste form degradation and consequent mobilization of radionuclides, reactive transport through the near field environment (waste package and engineered barriers), and transport into and through the geosphere. Science, engineering, and technology improvements may advance our understanding of waste isolation in generic deep geologic environments and will facilitate the characterization of the natural system and the design of an effective engineered barrier system for a demonstrable safe total system performance of a disposal system. DOE is required to provide reasonable assurance that the disposal system isolates the waste over long timescales, such that engineered and natural systems work together to prevent or delay migration of waste components to the accessible environment.

Mined geologic repository projects and ongoing generic disposal system investigations generate business 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 consider proposals that may contribute to a better understanding of barrier system performance, the optimization of repository performance, and systems characterization and monitoring. Proposals supporting the development of materials, test equipment, testing methods, and modeling tools relevant to permanent disposal of spent nuclear fuel and high-level radioactive waste for a variety of generic mined disposal concepts (in clay/shale, salt, crystalline rock, and tuff). Proposals sought 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 chemically reducing repository environment leading to the development of improved models (including uncertainties) to represent the waste container/package long term performance
- Improved understanding of large-scale hydrologic and radionuclide transport processes in the geosphere of relevant disposal repository environments, leading to the development of improved methodologies and models (including uncertainties) to represent these processes
- 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 new techniques for in-situ field characterization of hydrologic, mechanical, and chemical properties of host media and groundwater in a disposal system
- Development of new and cost-effective concepts (in different geologic media -- clay/shale, salt, crystalline rock, and tuff) for sealing repository openings (e.g., shafts, tunnels, wells) to facilitate repository closure and provide required long-term waste isolation and performance
- 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.

Several reports related to program areas of interest (generic geologic disposal environments, testing, and materials) are located at https://www.energy.gov/ne/listings/used-fuel-disposition-rd-documents .

Questions – Contact: Mark Tynan, Mark.Tynan@doe.gov

b. Spent Fuel and Waste Science and Technology, Storage & Transportation R&D

The possibility of chloride-induced stress corrosion cracking (CISCC) in welded stainless-steel dry storage canisters (DSC) for spent nuclear fuel (SNF) has been identified as a potential concern regarding long-term performance of the canister's containment boundary. During canister fabrication, the welding procedure introduces high tensile residual stress and sensitization in the heat-affected zone (HAZ), which might render the welds susceptible to the incubation of pitting and transition to crack initiation and growth when exposed to an aggressive chemical environment. Analysis of canister surface samples from in-service DSCs at three near-marine ISFSI sites have demonstrated the presence of chloride-rich salts on the outer canister surfaces (Enos et al. 2013, Bryan and Enos 2014, EPRI 2014, Bryan and Enos 2015). As portions of the canister surfaces cool sufficiently, the marine atmospheric salts may deliquesce and generate an aqueous brine layer on the surface of the canisters at various locations. This aggressive environment in contact with a susceptible HAZ could potentially lead to pitting, CISCC, and through-wall penetration in the HAZs of the canister welds. A through-wall penetration would breach the canister's containment boundary.

To reduce the potential for a through-wall CISCC and breach of the canister's containment boundary, it would be beneficial to develop detection, interpretation, and mitigation technologies for the pits and cracks. The incentive for developing these technologies is to arrest the process before through-wall penetration, thus avoiding the cost of repackaging the SNF into replacement canisters and the related nuclear-safety issues. The detection, interpretation, and mitigation technologies must be capable of in-situ application on loaded systems (i.e., canister remains within storage overpack), and must be limited to low heat input and acceptable external forces to avoid significant reduction in mechanical strength and deformation of the dry storage canisters. These technologies could help maintain the mechanical integrity and containment boundaries of the original canisters, and support the continuation of the long-term performance of dry storage canisters.

Small Business Innovative Research proposals are sought for the development of detection, interpretation, and mitigation technologies for the pits and cracks in the HAZs of the canister welds.

Key research contributions shall include one or more of the following:

- Develop an in-situ continuous monitoring system for real-time canister structural health and integrity monitoring.
- Develop a machine learning tool with online database development capabilities for predictive detection and interpretation of metastable pits and incipient cracks on canister surfaces.
- Develop novel local stress relief and/or in situ crack mitigation capabilities.

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@doe.gov

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