FY 2019 EERE Small Business Innovation Research (SBIR) & Small Business Technology Transfer (STTR) Topics

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

a. Innovation in solar module manufacturing processes and technologies

17. JOINT TOPIC: ADVANCED MANUFACTURING AND GEOTHERMAL TECHNOLOGIES OFFICES

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

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

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.

1. 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 N2, O2, Ar, CO2, 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 Hardy, david.hardy@ee.doe.gov

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References: Subtopic b:

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2. 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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3. 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: James R. Brodrick, james.brodrick@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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4. 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

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 CO_2 and H_2 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 H_2) 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 CO_2 and renewable H_2 and adapted to utilizing renewable energy sources.

Firstly, the processes and catalysts have to be modified to operate with CO_2 instead of CO in the feed. Conversion of CO_2 into CO in a reverse Water-Gas-Shift (RWGS) process is one option. Direct synthesis from CO_2 and H_2 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

References:

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1. Sprik, S., Kurtz, J., Saur, G., Onorato, S., et al, 2018, Next Generation Hydrogen Station Composite Data Products: All Stations (Retail and Non-Retail Combined)—Data through Quarter 4 of 2017, National Renewable Energy Laboratory, p. 110. https://www.nrel.gov/docs/fy18osti/71644.pdf

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2. California Fuel Cell Partnership, 2017. http://cafcp.org/stationmap

3. Barthélémy, H., Weber, M., Barbier, F., Furtado, J., et al, 2017, Hydrogen Storage: Recent Improvements and Industrial Perspectives, International Journal of Hydrogen Energy, Vol. 42, Issue 11, p. 7254-7262. https://www.hysafe.info/wp-content/uploads/2017_papers/293.pdf

5. 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

2. Tester, J. W., Livesay, B., Anderosn, B. J., Moore, M. C., et al, 2006, The Future of Geothermal Energy: Impact of Enhanced Geothermal Systems (EGS) on the United States in the 21st Century, Massachusetts Institute of Technology, p. 372. https://www1.eere.energy.gov/geothermal/pdfs/future_geo_energy.pdf

3. Downhole telemetry, IADC. http://drillingmatters.iadc.org/glossary/downhole-telemetry/

4. Almeida Jr., I. N., Antunes, P. D., Gonzalez, F. O. C., et al, 2015, A Review of Telemetry Data Transmission in Unconventional Petroleum Environments Focused on Information Density and Reliability, Journal of Software Engineering and Applications, Vol. 8, p. 455-462. https://file.scirp.org/pdf/JSEA_2015090414401392.pdf

6. 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

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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

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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

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

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

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1. U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (DRIVE), 2018, Advanced Combustion and Emission Control Roadmap, U. S. Department of Energy, p. 53. https://www.energy.gov/sites/prod/files/2018/03/f49/ACEC_TT_Roadmap_2018.pdf

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1. Vehicle Technologies Office, 2017, Materials Technical Team Roadmap, U. S. Department of Energy, p. 13. https://www.energy.gov/eere/vehicles/downloads/us-drive-materials-technical-team-roadmap

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8. 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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9. 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

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10. 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

References:

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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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11. 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

12. 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/