U.S. Department of Energy

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

Topics

FY 2024

Phase I

Release 2

Version 7, January 18, 2024

- Office of Cybersecurity, Energy Security, and Emergency Response
- Office of Defense Nuclear Nonproliferation
- Office of Electricity
- Office of Energy Efficiency and Renewable Energy
- Office of Fossil Energy and Carbon Management
- Office of Nuclear Energy

Schedule

Event	Dates
Topics Released:	Monday, November 6, 2023
Funding Opportunity Announcement Issued:	Thursday, January 18, 2024
Letter of Intent Due Date:	Friday, February 2, 2024, 5:00pm ET
Application Due Date:	Tuesday, March 12, 2024, 11:59pm ET
Award Notification Date:	Monday, June 10, 2024*
Start of Grant Budget Period:	Monday, July 22, 2024

*** Date Subject to Change**

Table of Changes		
Version	**Date**	**Change**
Ver. 1	Nov. 05, 2023	Original
Ver. 2	Nov. 14, 2023	• Topic C58-01: Updated Topic Description • Topic C58-23: Updated Topic Description • Topic C58-24: Updated Topic Description • Topic C58-25: Updated Topic Description • Topic C58-26: Updated Topic Description • Topic C58-27: Updated Topic Description • Topic C58-28: Updated Topic Description
Ver. 3	Nov. 17, 2023	• Topic C58-13, subtopic b: Updated Subtopic Description • Topic C58-18, subtopic a: Updated Point of Contact • Topic C58-18, subtopic b: Updated Point of Contact • Topic C58-18, subtopic c: Updated Point of Contact • Topic C58-29, subtopic cc: Added Subtopic • Topic C58-30, subtopic e: Removed Subtopic
Ver. 4	Nov. 21, 2023	• Topic C58-28: Updated Topic Description • Topic C58-28, subtopic c: Updated Subtopic Description
Ver. 5	Nov. 28, 2023	• Corrected topic numbering to match the table of contents.
Ver. 6	Dec. 8, 2023	• Topic C58-23, subtopic c: Updated Subtopic Description and Added Reference • Topic C58-25, subtopic a: Updated Technical Point of Contact • Topic C58-29, subtopic i: Updated Technical Point of Contact • Topic C58-29, subtopic j: Updated Technical Point of Contact • Topic C58-29, subtopic k: Updated Technical Point of Contact
Ver. 7	Jan. 18, 2024	• Schedule: Updated Dates

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INTRODUCTION TO DOE SBIR/STTR TOPICS

This SBIR/STTR topics document is issued in advance of the FY 2024 DOE SBIR/STTR Phase I Release 2 Funding Opportunity Announcement scheduled to be issued on December 11, 2023. The purpose of the early release of the topics is to allow applicants an opportunity to identify technology areas of interest and to begin formulating innovative responses and partnerships. Applicants new to the DOE SBIR/STTR programs are encouraged to attend upcoming topic and Funding Opportunity Announcement webinars. Dates for these webinars are listed on our website: https://science.osti.gov/sbir/Funding-Opportunities.

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

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

BIL FUNDED PROJECTS

Specific subtopics that will utilize BIL funding will have additional application requirements and award terms and conditions. Please refer to the Funding Opportunity Announcement (scheduled to be issued on December 11, 2023, for those BIL-specific changes.)

PARTNERING RESOURCES

The Office of SBIR/STTR Programs has released its SBIR Partnering Platform that helps applicants and awardees (***INNOVATORS***) identify and engage with the myriad of partners (***PARTNERS***) required throughout technology development and productization. Partners registered on the platform include industry stakeholders, investors, national labs, academia, and related ecosystems and include subject matter experts (SMEs), collaborators, subcontractors, manufacturers, engineering/prototype designers, test/certification resources as well as TABA business service providers (accounting, market research, strategy, grant writing, marketing materials, web design), etc. The platform offers key word searching as well as AI to find and identify funding opportunities as well as partners, confidential messaging between parties and bookmarking of identified favorites.

Looking to engage with the National Laboratories to find SMEs, subcontractors, collaborators or even patented technologies to license for commercial development? Visit https://labpartnering.org/labs to search opportunities at each laboratory.

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

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COMMERCIALIZATION

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

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

Publicly available market research studies. As part of our Phase 0 Application Assistance Program, the DOE Program Offices participating in SBIR/STTR have commissioned various market research studies related to SBIR/STTR topic areas. Many of these reports are publicly available on our website to facilitate commercialization planning for SBIR/STTR applicants and awardees.

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

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

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

For additional information regarding CESER's activities and priorities, click here. Click here to read the CESER Blueprint. Information regarding current RMT' funding can be found here. Note: RMT was formerly called Cybersecurity for Energy Delivery Systems (CEDS).

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

C58-01. ENERGY SYSTEMS CYBERSECURITY

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

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

All applications this topic must:

- Clearly provide understanding of current capabilities and outline the novelty of the proposed solution.
- Propose a tightly structured project which includes technical and business milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative;
- Demonstrate a clear understanding of the OT process/system that is being protected and how the solution will protect without interrupting reliability and normal operations;
- For any solution intended for onsite installation; fully justify the compatibility with the electro-magnetic and other environmental conditions of the intended site;
- Clearly describe the commercialization potential of the federally-funded effort and provide a detailed path to scale up in potential transition to industry practice.

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

All applications to this topic should:

- Prioritize the reduction of catastrophic cyber risk and measures that enhance strategic stability for the nation's energy infrastructure.
- Emphasize technologies that ensure safe, clean, and reliable access to critical functions and safety information systems without obstructing normal operations.
- Clearly define the merit of the proposed innovation compared to competing approaches and the anticipated outcome.
- Be consistent with and have performance metrics (whenever possible) linked to published, authoritative analyses in your technology space.
- Include quantitative projections for price and/or performance improvement that are tied to representative values included in authoritative publications or in comparison to existing products.
- Fully justify all performance claims with thoughtful theoretical predictions and/or experimental data.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Grant applications are sought for the following subtopic:

a. Cybersecurity for Electric Vehicle Charging Infrastructure (EVCI)

The lack of charging infrastructure often is cited as a primary barrier to increased adoption of Electric Vehicles (EVs).[1] The federal government has several efforts underway that assist with the transition towards electric vehicle adoption:

- The Bipartisan Infrastructure Law, Public Law (P.L.) 117-58, contains several provisions for electric transportation including up to $7.5 billion in funding for EV charging infrastructure, $5 billion for electric school buses, and $5.6 billion for electric transit buses.
- Executive Order (EO) 14057 states a goal for the federal fleet to transition to zero-emission vehicles (including EVs) for all light-duty vehicles purchased by 2027.

The development of capabilities such as tools, techniques, and/or methodologies that address gaps related to infrastructure/software architecture for securing EVCI. Solutions need to take into consideration reliability requirements and the custom engineered nature of most Electric Vehicle Supply Equipment (EVSE). Proposed solutions can include but are not limited to sandbox environments to exercise scenarios, solutions that promote self-healing from intrusion or malicious attacks, an intelligent response capability to recognize a malicious activity/compromise and then concurrently factor the associated risks and impacts of various mitigation responses holistically on the connected energy system, threat detection and monitoring tools into the rapidly developing EV charging infrastructure, tamper detection alerts, and randomized delay functionality.

The proposed solution must be applicable for EVSE in a commercial application such as public or private charging infrastructure. Dual use is ok for the proposed commercial solution to also be used for federal/military applications. Solutions proposed for personal applications such as home charging will be

[1] https://www.eei.org/-/media/Project/EEI/Documents/Issues-and-Policy/Electric-Transportation/EV-Forecast--Infrastructure-Report.pdf

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considered non-responsive to the solicitation. Additionally, the proposed solution must clearly indicate whether the intended use case is for Level 2 or Level 3 EVSE and incorporate that into impact projections and commercialization plan.

Questions – Contact: Joseph Dygert, Joseph.dygert@netl.doe.gov

References:

1. McCarthy, J., et al., 2023, “Cybersecurity Framework Profile for Electric Vehicle Fast Charging Infrastructure.” NIST IR 8473, 2023, https://csrc.nist.gov/pubs/ir/8473/final (October 20, 2023)
2. Hamdare, Safa et al., 2023, “Cybersecurity Risk Analysis of Electric Vehicles Charging Stations.” Sensors (Basel, Switzerland) vol. 23,15 6716., doi:10.3390/s23156716, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10422437/ (October 20, 2023)
3. Metere, Roberto, et al., 2021, "Securing the electric vehicle charging infrastructure." arXiv preprint arXiv:2105.02905, https://arxiv.org/pdf/2105.02905.pdf (October 20, 2023)
4. Satterfield, Charles, and Kellen Schefter, 2022, "Electric vehicle sales and the charging infrastructure required through 2030," https://www.eei.org/-/media/Project/EEI/Documents/Issues-and-Policy/Electric-Transportation/EV-Forecast--Infrastructure-Report.pdf (October 20, 2023)
5. The White House, 2021, “Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability,” Executive Order Number 14057, https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/ (October 20, 2023)

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

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

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

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

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

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

This office seeks grant applications in the following topic areas:

C58-02. QUANTUM SENSORS FOR UNDERGROUND NUCLEAR EXPLOSION MONITORING

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

The Office of Nuclear Detonation Detection (NDD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to develop new technologies for monitoring underground nuclear explosions. Emerging sensor hardware and software developments have the potential to provide precise timing of various sensing modalities used in underground nuclear explosion monitoring (e.g., seismoacoustic signals in the subsurface, infrasound in the atmosphere, and potentially other signals of diagnostic value such as high precision electromagnetic or acoustic measurements). Currently available quantum electromagnetic sensors (Savukov et al., 2017) provide potentially useful detection thresholds in configurations that can be fielded with small areal footprints. Nuclear explosion monitoring applications require fieldable sensors with minimal size, weight, and power.

Grant applications are sought in the following subtopics:

a. Fieldable Quantum Sensors to Detect Underground Explosions

Quantum sensing of motion – including acceleration (e.g., gravity) and rotation (which can generate electric and magnetic fields) – and of imaging have enabled precision measurements in materials science and fundamental physics by measuring physical quantities using atomic properties, minimizing sensor drift and the need to calibrate. Quantum sensor technology is evolving with breakthroughs such as the ability to measure an arbitrary frequency (Wang et al., 2022). In recent years, the size and volume of quantum electromagnetic (EM) sensors have been drastically reduced, with further improvements potentially achievable for magnetic sensitivity at the millisecond time-scale in sensors robust enough to be deployed in environmental settings (Li et al., 2020), as with applications of optically pumped magnetometers (OPMs). Quantum measurement for ultra-sensitive detection of acoustic waves is another emerging technology (Satzinger et al., 2018) in which potential approaches could leverage squeezed light to enhance fringe measurement resolution. A "quantum microphone" has the potential to be more sensitive than classical techniques.

The Office of Nuclear Detonation Detection is soliciting research in quantum sensor approaches useful in underground nuclear explosion monitoring applications, in which dynamic seismoacoustic and electromagnetic energy is propagated (Sweeney, 1989; Soloviev et al, 2002). Of interest are methods that would lead to sensors fieldable in rugged environments with practical size, weight, and power requirements and data transmission rates that provide ultra-sensitive detection of signals in outdoor environments.

Example device characteristics may include, but are not limited to, a sensor that can operate in any orientation in earth's magnetic field, <5 pT/rt-Hz magnetic sensitivity, minimum data rate of 2k samples/sec for millisecond timing resolution, and military spec (-55 to 125 °C) temperature range for the whole device.

Questions – Contact: John Lazarz, John.Lazarz@nnsa.doe.gov

b. Other

In addition to the specific subtopics listed above, grant applications in other areas relevant to this topic are invited. These include seismometer improvements (e.g., reduced size, improved sensitivity, reduced power requirements), seismic array improvements, infrasound sensor improvements (Dannemann Dugick et al., 2023), hydroacoustic sensor improvements, or other ways to detect acoustic energy underground (Maceira et al., 2017), on the surface, or in the atmosphere at regional to global distances (>200km) (Kalinowski et al., 2021). Improvements should substantially enhance capabilities when compared to existing sensors or techniques.

Questions – Contact: John Lazarz, John.Lazarz@nnsa.doe.gov

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References: Subtopic a:

1. Li. R., et al., 2020, Continuous High-Sensitivity and High-Bandwidth Atomic Magnetometer, Phys. Rev. Applied 14, 064067, DOI: 10.1103/PhysRevApplied.14.064067 https://journals.aps.org/prapplied/abstract/10.1103/PhysRevApplied.14.064067 (October 19, 2023)
2. Satzinger, K.J., et al., 2018, Quantum Control of Surface Acoustic-Wave phonons, Nature 563, 661–665 (2018), DOI: 10.1038/s41586-018-0719-5 https://www.nature.com/articles/s41586-018-0719-5 (October 19, 2023)
3. Savukov, I., et al., 2017, High-sensitivity Operation of Single-Beam Optically Pumped Magnetometer in a kHz Frequency Range, Measurement Science and Technology 28.3, DOI: 10.1088/1361-6501/aa58b4 https://iopscience.iop.org/article/10.1088/1361-6501/aa58b4/pdf (October 19, 2023)
4. Soloviev, S. P., Surkov, V. V., and Sweeney, J.J., 2002, Quadrupolar Electromagnetic Field from Detonation of High Explosive Charges on the Ground Surface, J. Geophys. Res., V. 107, no. B6, pp. 211., DOI: 10.1029/2001JB000296 https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2001JB000296 (October 19, 2023)
5. Sweeney, J.J., 1989, An Investigation of the Usefulness of Extremely Low-Frequency Electromagnetic Measurements for Treaty Verification, Report UCRL-53899, Lawrence Livermore Natl. Lab., Livermore, CA., DOI: 10.2172/6294530 https://www.osti.gov/biblio/6294530/ (October 23, 2023)
6. Wang, G., et al., 2022, Sensing of Arbitrary-Frequency Fields Using a Quantum Mixer, Phys. Rev. 12, 021061, DOI: 10.1103/PhysRevX.12.021061 https://www.bing.com/ck/a?!&&p=467cf3179ccdf7f6JmltdHM9MTY5ODc5NjgwMCZpZ3VpZD0yNjY1YjQ5Mi1lZmY4LTY1NmQtMTMzYy1hN2NiZWU0ZjY0NTAmaW5zaWQ9NTIxNw&ptn=3&hsh=3&fclid=2665b492-eff8-656d-133c-a7cbee4f6450&psq=Sensing+of+Arbitrary-Frequency+Fields+Using+a+Quantum+Mixer%2c+Phys.+Rev.+12%2c+021061&u=a1aHR0cHM6Ly9qb3VybmFscy5hcHMub3JnL3ByeC9wZGYvMTAuMTEwMy9QaHlzUmV2WC4xMi4wMjEwNjE&ntb=1 (October 23, 2023)

References: Subtopic b:

1. Dannemann Dugick, F. K., et al., 2023, Introduction to the Special Section on Seismoacoustics and Seismoacoustic Data Fusion, Bull. Seismol. Soc. Am. 113, 1383-1389, DOI: 10.1785/0120230049 https://pubs.geoscienceworld.org/ssa/bssa/article-abstract/113/4/1383/624450/Introduction-to-the-Special-Section-on?redirectedFrom=fulltext (October 23, 2023)
2. Kalinowski, M.B., et al., 2021, Introduction to the Topical issue of nuclear explosion monitoring and verification: scientific and technological advances, Pure and Applied Geophysics 178, 2397-2401, DOI: 10.1007/s00024-021-02783-2 https://link.springer.com/article/10.1007/s00024-021-02783-2#citeas (October 23, 2023)
3. Maceira, M., et al., 2017, Trends in Nuclear Explosion Monitoring Research & Development – A Physics Perspective, Technical Report No. LA-UR-17-21274. Los Alamos National Lab.(LANL), Los Alamos, NM United States, DOI: 10.2172/1355758 https://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-17-21274 (October 23, 2023)

C58-03. RADIATION RESISTANT PLASTIC ENCAPSULATED MICROCIRUITS

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

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

a. Radiation Resistant Plastic Encapsulated Microcircuits (PEMs) with Undiminished Performance, High-Yield, and Lower Cost

Long duration space-based missions would greatly benefit from the availability of inexpensive and rapidly developed radiation resistant microcircuits. PEMs are of keen interest in this regard for the new generation of proliferated spacecraft constellations being generated by commercial entities and the military. Of particular interest is the potential for PEMs to augment space qualified parts which are rare, expensive, have extraordinary lead times, and quickly obsolete with time. Most government agencies and commercial entities involved in spacecraft development understand that the need for faster, cheaper, and more abundant electronic parts is never going to diminish.

Related questions are: can PEMs meet the reliability requirements of space-based missions? Can they be screened? Do post-delivery tests and evaluations provide sufficient knowledge of the parts to satisfy mission requirements? Can PEMs ever be expected to last 15 years in space environments? What, if anything, can be done post-manufacturing to gain additional confidence in the suitability of PEMS part for long term use in space?

Doped plastic encapsulation methods are of particular interest in a quest to achieve space qualified parts. PEMs capable of high radiation resistance, undiminished performance, rapid development, and low-cost are the ultimate objectives of this research.

The Office of Nuclear Detonation Detection is soliciting research to develop radiation resistant microcircuit plastic encapsulation methods capable of meeting the following specifications:

- Radiation survivability: up to 100 Mrad
- Minimizing Bremsstrahlung Effects
- Undiminished performance due to incident radiation
- Functional production yields > 80%
- Materials cost: 5-10 times lower than standard space qualified parts

A Phase I research effort could identify the candidate materials and their potentials and demonstrate pathways for meeting radiation resistance and cost performance goals.

Questions – Contact: Captain Christopher McCartan, Chris.McCartan@nnsa.doe.gov

b. Other

In addition to the specific subtopic listed above, grant applications in other areas relevant to subtopic a. are also invited, such as other techniques to achieve some or all of the requirements for PEMS specified in subtopic a.

Questions – Contact: Captain Christopher McCartan, Chris.McCartan@nnsa.doe.gov

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References:

1. More, C.V., et al. 2021, Polymeric Composite Materials for Radiation Shielding: A Review, Environ Chem Lett. 2021;19(3):2057-2090. doi: 10.1007/s10311-021-01189-9. Epub 2021 Feb 3. PMID: 33558806; PMCID: PMC7857349, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7857349/ (October 23, 2023)
2. White, II, G.V., 2013, An Overview of Basic Radiation Effects on Polymers and Glasses, United States: N. p., https://www.osti.gov/servlets/purl/1671997 (October 23, 2023)

PEM Standards:

3. SAE International, 2017, Requirements for Plastic Encapsulated Microcircuits in Space Applications, AS6291/1, https://www.sae.org/standards/content/as6294/1/ (October 23, 2023)
   This document establishes common industry practices and recommended screening, qualification, and lot acceptance testing of Plastic Encapsulated Microcircuits (PEMs) for use in space application environments.
4. SAE International, 2019, Requirements for Plastic Encapsulated Discrete Semiconductors in Space Applications, AS6291/3, https://www.sae.org/standards/content/as6294/3/ (October 23, 2023)
   This document establishes the requirements for screening, qualification, and lot acceptance testing of Plastic Encapsulated Discrete Semiconductors (PEDS) for use in space application environments. The scope of this document is intended for standard silicon based technology only, but the process and methodology described within can be adopted for other technologies such as Silicon Carbide, Gallium Nitride, and Gallium Arsenide. However, when non-silicon based technology parts are being used, the device characterization shall be modified, and it is recommended to use available industry standards based upon published research/testing reports for those technology to address applicable physics of failure.
5. U.S. Department of Defense, 2013, Performance Specification: Integrated Circuits(Microcircuits) Manufacturing, General Specification For, MIL-PRF-38535 Rev K, http://everyspec.com/MIL-PRF/MIL-PRF-030000-79999/MIL-PRF-38535K_48842/ (October 23, 2023)
6. Agarwal, S., 2013, CLASS Y STATUS OVERVIEW (Infusion of New Technology into DoD Standards), NASA Electronic Parts & Packaging Program (NEPP), Electronics Technology Workshop (ETW), GSFC, Greenbelt, Maryland June 11-12, 2013, https://nepp.nasa.gov/workshops/etw2013/talks/Tue_June11_2013/1300_Agarwal_Class%20Y%20Status%20Overview.pdf (October 24, 2023)

C58-04. ARTIFICIAL INTELLIGENCE

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

The Office of Proliferation Detection (PD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to develop and demonstrate trustworthy, effective, and deployable Artificial Intelligence (AI) technologies. Meeting this objective requires the ability to experiment with static multimodal foundation models and dynamic AI systems to identify emergent behavior, vulnerabilities, and threats as well as to develop approaches for aligning foundation models with scientific disciplines, concepts, and goals. Grant applications are sought in the following subtopic:

a. Experimentation Framework for Multimodal Foundation Models

Frameworks and tools are needed to enable implementation and deployment of experimentation sandboxes and testbeds for red-teaming and evaluation of static and dynamic AI systems built upon multimodal foundation models. Red-teaming and evaluating foundation models can be resource intensive (both compute

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and human), therefore research efforts would benefit from approaches that include an appropriate level of open-source engagement and collaboration as well as support for novel approaches to compute such as use of cloud spot instances. Possible evaluation methods include, but are not limited to, prompt injection, data poisoning, jailbreaking, and backdoor attacks. The proposed framework should include metrics for trustworthiness (e.g., robustness, transparency, explainability) and support measuring performance against benchmarks for downstream tasks. The final report shall describe the framework, technical approach to demonstrating one or more of the listed evaluation methods and plans for implementation and demonstration.

Questions – Contact: Paul Adamson, paul.adamson@nnsa.doe.gov

References:

1. Horawalavithana, S., et al., 2023, SCITUNE: Aligning Large Language Models with Scientific Multimodal Instructions, arXiv:2307.01139 [cs.CV], https://doi.org/10.48550/arXiv.2307.01139 (October 23, 2023)
2. Gupta, M., 2023, From ChatGPT to ThreatGPT: Impact of Generative AI in Cybersecurity and Privacy, IEEE Access, vol. 11, pp. 80218-80245, 2023, doi: 10.1109/ACCESS.2023.3300381 https://ieeexplore.ieee.org/document/10198233 (October 23, 2023)
3. Bommasani, R., et al., 2021, On the Opportunities and Risks of Foundation Models, Center for Research on Foundation Models (CRFM), Stanford University, https://doi.org/10.48550/arXiv.2108.07258 https://arxiv.org/abs/2108.07258 (October 23, 2023)

C58-05. AUTONOMOUS RADIATION SENSING AND MAPPING

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

The Office of Proliferation Detection (PD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to improve the speed, sensitivity, and resolution of radiation detection and mapping capabilities in a broad range of mission areas. The office is interested in developing automated sensor systems to perform these tasks at an enhanced level, particularly in areas where human bandwidth is limited, such as source search or commodity inspection, or conditions are hazardous, such as in facility assessment. Grant applications are sought in the following subtopics:

a. Autonomous Sensors Systems for Radiation Detection and Mapping

There is a broad swath of radiation detection scenarios in which an autonomous sensor or sensor network could significantly enhance capabilities and improve human safety: in cargo inspections, via the capacity to quickly survey a broad collection of containers to determine the presence of illicit nuclear materials, particularly in areas that humans cannot easily reach or where they are not permitted due to safety concerns; in efforts to localize the presence of nuclear sources across a wide-area; and in nuclear facility assessments, where measurements conducted by humans can represent an additional health risk.

Recent advances in nuclear sensing and computer vision delivered unprecedented capabilities in the detection, mapping, and visualization of complex radiation fields from mobile platforms [1]. With the advent of quadruped and humanoid robots, there are an increasing number and variety of robots available to be deployed for robotic applications of radiation detection ranging from source search to facility assessment, with many more to come in the near future. Autonomous capabilities are needed both for general radiation detection and robotics applications.

The Office of Proliferation Detection is soliciting proposals for autonomous sensors capable of performing in one or more of the following mission spaces (cargo inspection, wide-area search, facility assessment) leveraging recent advances in the fields of nuclear sensing, computer vision, artificial intelligence, machine learning, and unmanned aerial/ground vehicles. Such sensors should have real-time data fusion capabilities that merge signals from the on-board radiation sensor suite with contextual sensor signals to enable visualization, scene mapping, and geolocation. The autonomous platform should have robotic capabilities that would enable remote operation as well as the ability for self-guided routing or route adjustments driven by a dynamically created radiological map in near real-time by the on-board sensors. Platforms with robotic capabilities that enable transit by ground, aerial flight, and climbing, should all be considered, and proposals should establish methods for being able to communicate and coordinate across multiple autonomous platforms. Other desirable considerations of system effectiveness include, but are not limited to:

- Enhanced detection limits of the radiation sensor suite and imaging spatial resolution beyond the current state-of-the-art;
- The ability to calibrate the radiological field map;
- Environmental- and operational condition-driven autonomous path planning and navigation while generating a near real-time on-board 3-D map of the local environment;
- Capacity to conduct evasion planning to avoid obstacles or location constraints in order to complete missions in cluttered environments;
- Capability to operate in low-light, with and without GPS;
- Reduction of mechanical noise, e.g. vibrations
- Viability to fuse with additional sensing modalities.

Phase I goal is to develop an initial demonstrator with autonomous capability for radiation detection on a single robot. Phase II will expand the capability to perform autonomous sensing and mapping on a mixed group of robotic platforms.

Questions – Contact: Hank Zhu, hank.zhu@nnsa.doe.gov

b. Other

In addition to the specific subtopics listed above, grant applications in relevant technologies that can meet the objective of this topic are also invited.

Questions – Contact: Hank Zhu, hank.zhu@nnsa.doe.gov

References:

1. Dayani, P., et al., 2021, Immersive Operation of a Semi-Autonomous Aerial Platform for Detecting and Mapping Radiation, IEEE Transactions on Nuclear Science. PP. 1-1. 10.1109/TNS.2021.3122452 (2021), https://arxiv.org/abs/2103.10057 (October 23, 2023)

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C58-06. HIGH-ENERGY X-RAY SOURCES FOR FIELD RADIOGRAPHY

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

The Office of Proliferation Detection (PD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to improve field diagnostics technology for emergency responders in the instance of a potential nuclear threat. The office is interested in developing commercially available active interrogation sources for portable, high-energy radiography technologies.

Grant applications are sought in the following subtopics:

a. Novel X-Ray Sources for High-Energy Field Radiography

High Energy Radiography (HER) capabilities for nuclear incident emergency responders primarily reside in 7 MeV betatron-type particle accelerator systems, which accelerate an electron beam into a target to emit brehmstrlugg x-ray irradiation. These emitted x-ray photons are then used to perform penetrating imaging of objects on detector panels placed on the opposite side of the object from the betatron accelerator system. The objects of interest for responders can include particularly dense materials, thus necessitating the need for the high x-ray energies of such systems. These systems also have broad uses as part of non-destructive testing (NDT) methods in industrial radiography. While the betatron-type HER system is effective in its imaging capabilities it suffers from several limitations particularly critical to emergency responders with respect to its size, weight, and power (SWaP) as well as a lack of sufficient adjustability in its energy and dose outputs. Furthermore, supply chain issues have severely hindered the production of new and repair of existing betatron-based systems.

The Office of Proliferation Detection is soliciting proposals for non-betatron high-energy field radiography products. Current research and development of such alternative systems is based on advances in radio-frequency-driven linear accelerator (Linac) technology [1, 2] to achieve electron acceleration into the bremsstrahlung target. Proposals leveraging technologies other than Linac are also welcomed. However, it is critical that any proposed system at least meets the following listed requirements:

- Size/Weight/Power (SWaP): Volume of no larger than 16 cubic feet and weight of less than 200 lbs for entire system, with any separated “head” portion to be no more than 4 cubic feet and a weight of less than 100 lbs; dual power options for battery and wall power/generator (90-240 VAC at 20A or less)
- Energy: Minimum peak energy of 6-7 MeV, adjustable down to 2 MeV
- Dose Rate: Minimum peak output of 10 R/min at 1 meter, adjustable down to 0 R/min (zero dose, but overall system still active) at 1 meter with 0.1 R/min resolution
- Back Dose: 2mR/hr at less than 10 meters
- Duty Cycle: Minimum of 15 minutes of operation with maximum 15 minutes downtime.

The proposed system should also ideally feature a programmable dose rate, achieved through the setting of a current or by selection of a particular dose per pulse. It should also have an adjustable pulse rate in 1 Hz increments and an ability to adjust dose and pulse rate over time during integration.

Questions – Contact: Hank Zhu, hank.zhu@nnsa.doe.gov

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b. Other

In addition to the specific subtopics listed above, grant applications in relevant technologies that can meet the objective of this topic are also invited.

Questions – Contact: Hank Zhu, hank.zhu@nnsa.doe.gov

References:

1. Tantawi, S., et al., 2020, Design and Demonstration of a Distributed-Coupling Linear Accelerator Structure, Phys. Rev. Accel. Beams 23, 092001, https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.23.092001 (October 24, 2023)
2. Kutsaev, S.V., et al., 2021, Ir-192 Radioisotope Replacement with a Hand-Portable 1 MeV Ku-band Electron Linear Accelerator, Appl. Radiat. Isot. 179, 110029, https://www.sciencedirect.com/science/article/abs/pii/S0969804321004231 (October 24, 2023)

C58-07. ALTERNATIVE RADIOLOGICAL SOURCE TECHNOLOGIES

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

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

a. Novel Approaches to Accelerator Component Redesign to Address Supply Chain Uncertainty

A key mission of the Nuclear National Security Administration's (NNSA) Office of Radiological Security (ORS) is to ensure global security by preventing highly radioactive materials, such as Co-60, from being used for acts of terrorism. This ORS goal focuses on the reduction of global dependence on Cs-137 and Co-60 sources by promoting the adoption of non-radioisotopic technologies such as electron beam or X-ray devices used in commercial irradiation applications.

There is a growing demand for accelerator-derived radiation services in the U.S. and globally. Industries that will likely expand their use of accelerators include medical device sterilization, food and phytosanitary irradiation, and other industrial applications. Demand is expected to grow for the foreseeable future, especially due to current and potentially increasing limitations on access to radioisotope sources and ethylene oxide (a chemical used in medical device sterilization that is currently under scrutiny by the U.S. Environmental Protection Agency (EPA) due to human health concerns).

In the 2021 National Academies of Sciences (NAS) report on Radioactive Sources: Applications and Alternative Technologies [1] the authors outline pros and cons of radioactive sources and the alternative technology considered by users. Among the many factors that users considered were initial purchase costs and operation and maintenance costs, which are linked to the manufacturing and supply chain for critical accelerator components.

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In June 2023, ORS hosted the inaugural ORS Industry Day Workshop. Industry Day attendance included 49 representatives from USG agencies and 78 representatives from industry. U.S. government representatives included the Food and Drug Administration (FDA), the Department of Defense (DoD), Department of State, Defense Advanced Research Projects Agency (DARPA), Department of Commerce, U.S. Department of Agriculture, Department of Energy, and the NNSA. During the event, discussions and polling were conducted which identified areas of challenge for any substantial U.S. industry manufacturing growth in advanced nuclear technologies. During the 2-day event, manufacturers voiced a need for additional component suppliers and the need for consistent parts supply to maintain sustainable operation of their accelerator-based systems. Serious supply chain issues remain in the aftermath of the pandemic, and geopolitical tensions across the globe are causing disruptions to the accelerator supply chain. Manufacturers report the greatest supply gap is for radiofrequency systems (RF), including klystrons and magnetrons, which are essential for accelerator operation. RF systems remain in short supply and may require six months to a year for delivery after an order is placed. Other accelerator components face similar supply chain limitations as well.

NNSA ORS is interested in supporting the further development of the U.S. accelerator manufacturing and servicing industry. The adoption of machine-based accelerators, such as electron beam and X-ray, reduces the potential risks associated with theft or loss of radioisotopic sources employed in radiation services. The Office of Proliferation Detection is therefore soliciting the development of accelerator components in support of ORS with an emphasis on improvements in:

1. Minimizing manufacturing and supply costs, aiming to achieve prices comparable to non-domestic alternatives;
2. Reducing supply lead times, ideally below six months;
3. Enabling reliable maintenance.

Additionally, designs capable of being configured for multiple systems or fittings would be desirable to minimize the need for vendor redesign of operational systems. The component redesigns need to be capable of providing equivalent or superior performance for major service providers. The manufacturing process for these component redesigns should strive to be independent of single point supply chain failures. Improvements in power conversion efficiency for these systems beyond the state of the art would also be considered highly beneficial.

Questions – Contact: Hank Zhu, hank.zhu@nnsa.doe.gov

b. Other

In addition to the specific subtopics listed above, grant applications in relevant technologies that can meet the objective of this topic are also invited.

Questions – Contact: Hank Zhu, hank.zhu@nnsa.doe.gov

References:

1. National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Nuclear and Radiation Studies Board; Committee on Radioactive Sources: Applications and Alternative Technologies, 2021, Radioactive Sources: Applications and Alternative Technologies, Washington (DC): National Academies Press (US); 2021 Jun 14. PMID: 34524768, https://nap.nationalacademies.org/catalog/26121/radioactive-sources-applications-and-alternative-technologies (October 24, 2023)

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C58-08. TECHNOLOGY FOR FUTURE REMOTE DETECTION SENSING

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

The Office of Proliferation Detection (PD) within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to develop new technologies for remote detection systems for detecting, locating, and characterizing nuclear fuel cycle signatures and facilities. Remote detection is defined for DNN R&D as 100 m standoff and beyond but can include any available sensing modality or combinations of sensing types. The office is interested in developing advanced sensing modalities that take advantage of modern understanding of quantum phenomena to achieve higher sensitivity and performance. Grant applications are sought on the following subtopics:

a. Imaging Focal Planes Using Quantum Resonance Effects in the Pixels that are Adjustable in Sensing Frequency Through Application of a Control Signal (i.e., Thermal, Electrical, etc.)

Sensors that use resonance effects to couple incident EO radiation to signal production through geometric scaling of pixel dimensions have been demonstrated with high amounts of frequency specificity [1]. It is of interest to couple focal plane devices like these with a control mechanism that allows the resonant frequency to be adjusted across a significant range to fine-tune the signal collection [2]. Similar ideas have been applied in Quantum Cascade Lasers where a thermal control is used to adjust the dimensions of the lasing medium for fine tuning of emission frequency [3]. While thermal control is an option, similar effects could be possible through geometry control via other mechanisms (e.g., piezo-electric, magnetic, etc.). A primary focus is to demonstrate a suitable sensing mechanism with controllable resonant frequency.

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

b. Demonstration or Analysis of a Phased Array Gravity Sensor to Permit Off-Vertical Sensing Through Multi-Sensor Gravimeter or Gravity Gradiometer Systems Employing Atom Interferometers

Gravity sensing is proposed for detection of underground facilities, but the sensitivity of gravity detectors is a fundamental limitation for the stand-off distance that can be achieved. Research into gravity sensing instruments with greatly improved sensitivity using atom interferometers in both traditional and gradiometric configurations shows great promise [4]. A research direction that the office is interested in developing is using arrays of gravity sensors to improve sensitivity, reduce measurement times, or provide the ability to collect gravity data from non-nadir sensing directions. This is analogous to using arrays of acoustic or radar sensors and phased measurement techniques to collect off-axis signal information [5].

Demonstration of a physical instantiation of a gravity sensing array, or analysis that shows potential capability of a gravity sensor array toward these areas of improvement would provide insight into future technology development in this area.

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

c. Maritime, Limnologic, and Oceanic Hyperspectral Imagery Analysis Advancement

The maritime shipping industry is considering deployment of nuclear-powered vessels to significantly reduce their carbon dioxide emissions.[6] The nuclear nonproliferation community has an interest in ensuring the safe deployment and use of such vessels which can be effected via remote sensing.[7] Hyperspectral imagery is one remote sensing technology that can be implemented to assist nuclear power monitoring agencies for surface and subsurface environments.[8] Hyperspectral imagery data collected over bodies of water present unique analysis challenges.[9] This topic is an opportunity for development of advanced atmospheric correction methods that could include but not be limited to absorbing aerosols, identification of interference from bottom reflections, cloud absorption, light scattering in water, and absorption of other gases and or materials of interest. Algorithm development for removal of reflected light from the sea surface and optimization of viewing geometries from airborne or space platforms may also be considered. Analysis techniques in the near infrared, visible, and ultraviolet portions of the spectrum are of interest. Analysis workflow development should also be considered. Typical data collection can be on the order of 100s of GB of data. Attention should be given to efficient edge processing of hyperspectral data cubes to maximize analysis workflow efficiency.

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

References: Subtopic a:

1. Benz, A., Krall, M., Schwarz, S., et al., 2014, Resonant Metamaterial Detectors Based on THz Quantum-Cascade Structures, Sci Rep 4, 4269 (2014), https://doi.org/10.1038/srep04269 (October 24, 2023)
2. Li, S.Y., Zhang, H.F., 2023, An Actively Tunable Terahertz Metastructure Absorber with Tristate for Refractive Index Sensing Applications, Physica B: Condensed Matter, Volume 667, 2023, 415194, ISSN 0921-4526, https://doi.org/10.1016/j.physb.2023.415194 (October 24, 2023)
3. Zhou, W., Bandyopadhyay, N., Wu, D., et al., 2016, Monolithically, Widely Tunable Quantum Cascade Lasers Based on a Heterogeneous Active Region Design, Sci Rep 6, 25213 (2016), https://doi.org/10.1038/srep25213 (October 24, 2023)

References: Subtopic b:

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2. Merino-Martínez, R., Sijtsma, P., Snellen, M., et al., 2019, A Review of Acoustic Imaging Methods Using Phased Microphone Arrays, CEAS Aeronaut J 10, 197–230 (2019), https://doi.org/10.1007/s13272-019-00383-4 (October 24, 2023)

References: Subtopic c:

1. Megginson, R., Huston, T., 2023, Putting the Blue Back in Red, White and Blue - Decarbonisation of the US Maritime Industry with Advanced Nuclear, CORE POWER (UK) LTD, https://corepower.energy/report/red-white-blue (October 24, 2023)
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   Gillis, D.B., 2016, Detection of Underwater Objects in Hyperspectral Imagery, 2016 8th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS), Los Angeles, CA, USA, 2016, pp. 1-5, DOI: 10.1109/WHISPERS.2016.8071732, https://ieeexplore.ieee.org/document/8071732/authors#authors (October 24, 2023)
4. Tuenge, J., Arnold, G., et al., 2023, Radiometric Testing of Germicidal UV Products, Round 1: UV-C Towers and Whole-Room Luminaires, CALiPER Full Report, Office of EERE, PNNL-33824, https://www.energy.gov/sites/default/files/2023-09/ssl_caliper-guv-rd1-full.pdf (October 24, 2023)

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PROGRAM AREA OVERVIEW: OFFICE OF ELECTRICITY

The Office of Electricity (OE) leads the Department of Energy's efforts to ensure that the Nation's energy delivery system is reliable, resilient, secure, and affordable. Working closely with public and private partners funds the development of new technologies that enhance the infra structure that delivers electricity at the transmission and distribution levels across North America.

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

OE has a broad portfolio of activities that spans technology innovation, institutional support and alignment, and security and resilience. Serving as the lead for the Department of Energy's efforts on grid modernization, OE works closely with diverse stakeholders to ensure that the Nation's electricity delivery system is secure and resilient to disruptions and that clean energy technologies can be integrated in a safe, reliable, and cost-effective manner. These efforts will strengthen, transform, and improve electricity infrastructure so consumers have access to resilient, secure, and clean sources of energy.

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

C58-09. ADVANCED GRID TECHNOLOGIES

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

Electricity is the lifeblood of modern society, and many of the quality-of-life improvements in human history have been catalyzed by widespread access to affordable electricity. The ability to control, shape, and condition electric power is critical, and requires the use of power electronics. The electric power grid is facing increasing stress due to fundamental changes in both supply-side and demand-side technologies. On the supply-side, there is a shift from large synchronous generators to smaller, lighter units (e.g., gas-fired turbines) and variable invertor-based energy resources (renewables) with utility scale energy storage. On the demand-side, there is a growing number of distributed energy resources, as well as a shift from large induction motors to rapidly increasing use of electronic converters in buildings, industrial equipment, and consumer devices. The monitoring and control systems used for operations are also transitioning from analog systems to systems with increasing data streams and more digital control and communications from systems with a handful of control points at central stations to ones with potentially millions of control points distributed throughout the grid.

Grid modernization will require the adoption of advanced technologies, such as advanced power electronics, advanced transformers, smart meters, automated feeder switches, fiber optic and wireless networks, energy storage, and other new hardware. It must also encompass and enable the application of intelligent devices, next-generation components, cybersecurity protections, advanced grid modeling and applications, distributed energy resources, and innovative architectures. Integration of these technologies will require a new

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communication and control layer to manage a changing mix of supply- and demand-side resources, evolving threats, and to provide new services. Furthermore, key considerations for system designers include power density, efficiency, weight, cost, and reliability—attributes that impact the overall performance and market viability of a given technology. Since it is not possible to optimize all these attributes simultaneously, a designer may prioritize and make trade-offs based on application requirements.

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

All applications to this topic should:

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

Grant applications are sought in the following subtopic:

a. Extending Distribution Transformer Lifetime and Increasing Reliability Through Innovation

The electric grid is going through a modernization process with growing penetration of renewables and electric vehicles (EVs), multi-directional power flow, and demand-side management based on real-time data. This means a transition from centralized generation-based unidirectional power flow grid to a dynamic and fast-responsive grid with distributed generation, and in some cases with uncertain load profiles as more and more utility customers install EV chargers in homes, highlighting the critical role that transformers will continue to play in the grid modernization process.

Transformers are one of the fundamental building blocks of the electric grid; essentially all electric energy delivered flows through at least one. Through electromagnetic coupling, these components change the voltage of electric power, increasing it to transmit electricity more efficiently over long distances and decreasing it to a safe level for final delivery to end users. Distribution transformers are designed to accommodate a wide range of loading conditions and are typically located on poles and in enclosures within industrial, residential, and commercial areas, directly supplying power to the end user at low or medium voltages. Table 1 provides an overview of the different transformer classes and applicable voltage ratings.

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Table 1. Overview of General Grid Transformer Groups

Type	Class	Voltage Ratings
Power Transformers	Extra High Voltage	345-765 kV
	High Voltage	115-230 kV
	Medium Voltage	34.5-115 kV
Distribution Transformers	Distribution Voltage	2.3-34.5 kV

As the current demand for distribution transformers in the U.S outpaces manufacturing capacity, innovations that can extend the lifetime and increase reliability of currently deployed distribution transformers and other grid equipment are needed, especially distribution transformers located at the grid edge and in Front-of-The-Meter (FTM).

Applications and innovations are being sought at the transformer component level for ways to extend the lifetime and increase reliability of currently deployed distribution transformers. Desired innovations are cost-competitive, readily available, and can be retrofitted into currently deployed transformers. Other important aspects to compare include but are not limited to the additionality of enhanced functions and features, installation costs, operating lifetime, maintenance, size and weight (for transportation), and installed footprint. Applications must demonstrate quantitively how the proposed distribution transformer innovation in question can extend transformer lifetime and reliability over currently available technology.

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

References

1. U.S. Department of Energy, Office of Electricity Delivery & Energy Reliability, June 2020, Solid State Power Substation Technology Roadmap, https://www.energy.gov/oe/articles/solid-state-power-substation-technology-roadmap (October 18, 2023)
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C58-10. ADVANCED BATTERY MANAGEMENT AND SENSORS FOR GRID-TIED ENERGY STORAGE

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

Energy storage systems provide multiple technical and economic benefits to future electric utility grids. These

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systems can increase the value of renewables such as photovoltaic systems and wind energy, by providing flexibility for the customer, maintaining power quality, increasing asset utilization, and deferring upgrades of the grid. Grid-tied energy storage systems will ultimately improve the reliability, security, quality, flexibility, and the cost effectiveness of the existing and future electric utility infrastructure. Specifically, battery energy storage system (BESS) is made up of multiple critical components such as the battery system, battery management system (BMS), power conversion system (PCS), controller, SCADA, and energy management system (EMS).

Grant applications are sought in the following subtopic:

a. Advanced In-Situ Battery/Energy Management for Next Generation Battery Energy Storage Systems

The PCS controls the power supplied to and absorbed from the grid, simultaneously optimizing the battery performance, and maintaining grid stability. There are multiple types of energy storage and battery chemistries, and each has their own characteristics and control parameters that must be managed by the PCS. The BMS's primary function is to protect and safeguard the battery from damage during various grid-tied functions to ensure it operates within predetermine parameters of the state of charge (SOC), state of heath (SOH), voltage, temperature, and current. The battery chemistries and operational parameters are constantly changing and a robust, flexible, adaptable, expanded sensor capabilities, and integrated PCS and battery/energy management is needed to keep up with the evolving technology. In addition, the typical predetermined parameters are not enough to ensure significant increase in battery safety, reliability, and performance. The EMS capability integrated into the power module provides an interface between the converter and a supervisory host (e.g., SCADA) that can provide long-term power delivery and charge commands to support the AC grid such as demand-charge management or time-of-use arbitrage.

Applications are sought to develop and demonstrate the integration of sensing and control capabilities of the PCS controller, BMS, and EMS into a single platform, marrying the functionality of battery safety with the converter that interfaces to the utility grid. Providing a more direct approach between converter control and battery safety eliminates unnecessary communications links and sensor redundancy between each component.

Furthermore, with the evolution of battery technologies beyond current state-of-the-art (e.g., lithium-Ion and lead acid), a highly flexible battery management platform will be required that can provide additional sensing metrics as to current state of the battery, capturing sensor inputs currently not available or required for commercial 'off-the-shelf' battery management systems. This open-source BMS platform with a universal sensor interface could include in-situ high-accuracy cell impedance, gas, environmental, and physical sensors that provide better detection of the early signs of battery module degradation and failure while increasing performance, reliability, and safety.

The final design should show a significant increase in functionality over existing BESS architectures, cost reduction, and decrease in footprint compared to a traditional grid-tied designs.

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

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PROGRAM AREA OVERVIEW: OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

The Office of Energy Efficiency and Renewable Energy (EERE) accelerates the research, development, demonstration, and deployment of technologies and solutions to equitably transition America to net-zero greenhouse gas emissions economy-wide by no later than 2050, creating good paying jobs, and ensuring the clean energy economy benefits all Americans, especially workers and communities impacted by the energy transition and those historically underserved by the energy system and overburdened by pollution.

Achieving this goal in an equitable manner will require leveraging the expertise and talents of small businesses. EERE's FY 2024 Phase I SBIR/STTR topics are focused on five investment areas that are central pillars of the U.S. greenhouse gas (GHG) profile:

- *Decarbonizing the electricity sector*. To initiate a path to achieve a carbon pollution-free electricity sector no later than 2035, EERE's focus is to support technologies that will allow us to generate all electricity from clean, renewable sources. To transition to a carbon-free power sector, advancements are needed to continue to make major strides to integrate more renewable energy generation onto the grid, while ensuring it is reliable, secure, and resilient, even as it evolves.
- *Decarbonizing transportation across all modes: air, sea, rail, and road.* The transportation sector has historically relied heavily on petroleum, which supports over 90 percent of the sector's energy needs today; as a result, the sector has surpassed electricity generation to become the largest source of CO_2 emissions in the country. This investment area aims to develop and enable new zero emission light-duty vehicle sales; address the Nation's sustainable aviation fuel demands; and increase the commercial viability of hydrogen fuel cells for long-haul heavy-duty trucks.
- *Decarbonizing energy-intensive industries.* Industrial processes currently contribute as much as 20 percent of the Nation's carbon emissions. To phase out emissions, EERE will support approaches that rely on renewable energy and fuels such as hydrogen to power industrial processes, capture and use carbon emissions, and vastly improve efficiency.
- *Reducing the carbon footprint of buildings.* EERE supports efforts to reduce the carbon footprint of the U.S. building stock by 50% by 2035. Such advances will be made while maintaining or improving affordability, comfort, and performance.
- *Decarbonizing the agriculture sector, specifically focused on the nexus between energy and water.* Agriculture represents nearly 10 percent of the Nation's carbon emissions, and EERE looks to make investments that drive a cleaner agriculture sector.

Please note that each topic and subtopics may have unique requirements for responsive application submissions; review the requirements for each topic and subtopic carefully to ensure you are responsive to requirements where applicable.

C58-11. ADVANCED MATERIALS AND MANUFACTURING TECHNOLOGIES

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

EERE's Advanced Materials and Manufacturing Technologies Office (AMMTO) supports research, development and demonstrations of next-generation materials and manufacturing technologies needed to improve Americans' quality of life, increase U.S. industrial competitiveness and drive economy-wide decarbonization.

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AMMTO supports the national plan to revitalize American manufacturing, secure critical supply chains, and develop diverse innovation ecosystems leading to new manufacturing jobs and increased economic strength of the nation. AMMTO provides planning, management, and direction necessary for a balanced program of research, development, demonstration, and workforce development to support domestic manufacturing that is critical to achieving a clean, decarbonized economy.

This Topic reflects DOE's support for activities that develop Energy Technologies (subtopics a, b, d) as well as Next Generation Materials and Manufacturing Processes (subtopic c) and secure and sustainable materials (subtopics b, c).

Subtopics b and c in particular are part of AMMTO's overall strategy in energy storage technologies. These and other battery technologies in Table 1 as well as thermal storage technologies and non-battery electric storage are expected to play a key role in transforming the nation's infrastructures and economy in the coming years to meet the goal of decarbonizing the U.S. Economy by 2050. It is estimated that the demand for energy storage in the grid and transportation sectors alone to grow by 3-5x within the next decade [1]. Batteries are a key energy storage technology given the need to electrify transportation and industry as a major decarbonization strategy. Batteries also play a critical role in enabling today's digital and increasingly wireless society. This subtopic seeks projects aimed at improving manufacturing processes to increase the range of battery solutions while lowering their environmental impact.

AMMTO supports improving the manufacturability of emerging energy storage/battery technologies to accelerate their adoption and grow domestic manufacturing.

Table 1 shows the size range of potential battery storage applications. Subtopics a and b below are focused on advancing US micro- and lithium-ion battery manufacturing by providing small businesses the opportunity to develop more cost-efficient manufacturing platforms in two of the size ranges shown in orange.

Table 1 – Battery size ranges for various application areas

Application Area	**Battery Size (order of magnitude)**
Grid Storage	>10s of cubic meters
Electric Vehicles	1 cubic meter
Power Tools	10 cubic centimeters
Consumer and Mobile Devices	A few cubic cm
Advanced Sensors and wearable/implantable medical devices	<0.1 cubic cm

In March 2023, the DOE/AMMTO and National Renewable Energy Laboratory (NREL) launched a Microbattery Manufacturing Design Prize [2]. Later in 2023, AMMTO announced two Lab-Calls related to Li-ion Battery Manufacturing [3,4] To support and build on both of these efforts under this topic, AMMTO is seeking applications in subtopics b and c.

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Subtopic d builds on AMMTO's research conducted under its Microelectronics' Energy Efficiency Scaling for two decades initiative (EES2). The 20-year EES2 initiative recognizes that cross-cutting areas such as quantum computing will require partnerships across DOE and the federal government—especially with the National Science Foundation—to achieve their full energy efficiency potential.

All applications to this topic must:

- Clearly indicate the subtopic and area of interest;
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions using appropriate metrics, key performance parameters, or properties -- Justify all performance claims with theoretical predictions and/or relevant experimental data.
- Propose a tightly structured program which includes clearly defined, relevant materials and manufacturing RD&D metrics (including energy savings where applicable). The program should include quantitative technical milestones, timelines, and expected deliverables that demonstrate aggressive but achievable **progress towards meeting performance parameter targets;**
- Provide evidence that the proposer has relevant materials and or manufacturing experience and capability;
- Explain applications of project output and potential for future commercialization including projections for cost and/or performance improvements that are tied to a clearly defined baseline;

The Phase I application should detail material, design and/or bench scale systems that are scalable to a subsequent Phase II prototype.

Applications must be responsive to the following subtopics.

a. Energy Technologies: Innovations in Microbattery Manufacturing

As shown in Table 1, batteries can be a key enabler at much smaller scales than the grid or electric vehicles. Microbatteries, in this case considered to be batteries of $100mm^3$ or less in total cell volume are critical components in emerging microelectronics systems like advanced sensors and worn or implanted medical devices [3]. Emerging application spaces for microelectronics, such as smart factories, smart cities, and personal medical devices, often leverage wireless sensors taking in data and transmitting it – possibly after some on-node processing – to a central location for driving real-time understanding, control, and even automation [4]. These small devices and sensors have an increasing need for smaller batteries with better performance than today's commercial standards. Due to their small size, microbatteries have significantly different manufacturing requirements (e.g., tighter dimensional tolerances, lower production volumes, different chemistries etc.) that prevent companies from leveraging existing large-scale manufacturing processes [5]. This effectively separates the microbattery market from much of the battery supply chain ecosystem, which presents a major barrier to getting new battery chemistries and designs prototyped or commercialized. Additionally, markets for microbatteries can be a useful intermediary stage for the scale-up of new battery chemistries. With a wide range of battery chemistries -- and therefore possible energy densities -- as well as performance and safety needs for different applications, specific capacity limits are less important than size limits.

In summary, this subtopic in Phase I seeks proof-of-concepts for microbatteries that meet the targets in Table 2 below.

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Table 2: Key Metrics for area of interest (1): innovations in microbattery manufacturing

Increased yield and/or reliability of microbattery cells Incorporation of new and/or improved materials into cell manufacturing Reduced cost for production of microbatteries

Questions – Contact: Paul Syers, paul.syers@ee.doe.gov and Jeremy Mehta, Jeremy.Mehta@ee.doe.gov

b. Energy Technology: Eco-friendly Innovations in Manufacturing of Lithium Metal for Batteries

This subtopic seeks proposals for developing and/or scaling up innovations that improve the environmental impacts of lithium metal production for Li-ion batteries. Lithium metal has been broadly used in primary lithium metal batteries and for pre-lithiation in advanced lithium-ion batteries. Lithium metal is obtained by extracting lithium from lithium containing brines and minerals. Technical challenges include those generally related to mining operations such as costs related to equipment and energy consumption, carbon emission, the need for water, and water and air pollution. Specific challenges associated with the electroextraction of lithium metal from molten salts include a high demand for electricity and the production of chlorine gas [8]. Additionally, the final product, lithium metal, is very reactive and requires processing under an inert, anhydrous atmosphere, and effective packaging of the metal for shipping [9]. AMMTO seeks projects that focus on novel, sustainable, and scalable manufacturing to accelerate lithium metal production.

Table 3. Metrics for eco-friendly innovations in manufacturing of lithium metal for batteries

Li Metal Manufacturing Target	**Target Metric**
Reduction in manufacturing cost of state-of-the-art industrial Li-metal production	Applicant defined (e.g., cost, material use, etc.)
Reduction or elimination of toxic gas during electrolysis that produces Li-metal	Applicant defined (e.g., X % reduction)
Increase in energy efficiency of Li-metal-producing electrolysis	Applicant defined (e.g., battery manufacturing energy consumption, energy per kg produced, etc.)
Increase in sustainability or circularity of the Li-metal supply chain	Applicant defined

Questions – Contact: Changwon Suh, Changwon.suh@ee.doe.gov and Jeremy Mehta, Jeremy.Mehta@ee.doe.gov

c. Next Generation Materials and Manufacturing Processes: Low-Cost, Scalable Manufacturing of High-Purity MAX Phase Powders

This subtopic is focused on MAX phases of materials for harsh environment energy applications, including high-temperature coatings, high-temperature heat exchangers, concentrated solar power materials, high-temperature structural materials, liquid metal corrosion resistant materials and radiation-resistant cladding [1]. MAX phases that also provide energy functionality, such as enhanced conductivity [2] also are of interest. The focus of the research to be funded under this subtopic is on investigating both innovative material compositions and low-cost, scalable synthetic routes to high-purity MAX phase powders, $M_{n+1}AX_n$, where n = 1 to 4, and *M* is an early transition metal, *A* is an *A*-group (mostly IIIA and IVA, or groups 13 and 14) element and *X* is either carbon and/or nitrogen.

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MAX phases are a large family of materials with more than 150 different compositions that have been extensively investigated during the last 25 years. Titanium silicon carbide (Ti_3SiC_2) has been one of the most widely studied. The MAX phases possess layered structures with corresponding unique combinations of anisotropic properties that, like intermetallic phases, bridge the gap between metallic and ceramic properties.[3] For example, the strength of MAX phases does not change with temperature, which makes them highly attractive as potential structural materials in high-temperature applications. They also possess low densities, good machineability, high strength and a high Young's modulus at high temperature, high chemical resistance, excellent thermal shock resistance, self-healing properties, and thermal and electrical conductivities.[4] MAX phase powders are additionally, at this time, the only precursors to two-dimensional *M*Xene phases, which have garnered much interest the R&D community owing to their potential use in a variety of applications including enhanced conductivity. [5]

Unfortunately, the transfer of MAX phase technology to the application space has been limited by the unavailability of affordable highly pure commercial powders. The stability of MAX phases in some harsh external environments (e.g., self-healing performance and radiation tolerance) is significantly influenced by their intrinsic defect population (i.e., vacancies, interstitials, and anti-site pairs). It is, however, difficult to synthesize MAX phases with low impurities because of the propensity of metal carbide formation in the final product.[6] Generally, high-purity MAX powder synthesis requires high temperatures and/or high pressures.[7] However, other synthesis routes are possible, including liquid/solid state reaction methods (e.g., combustion synthesis, pressureless sintering, ball milling, hot pressing, spark plasma sintering, etc.), physical vapor deposition (PVD) techniques, and molten salt processes.

If affordable and scalable synthetic routes with a high yield (> 95 wt.%) can be developed for high-purity (≥ 99%) bulk (large quantities) MAX powders or powder fabrication of MAX phases, including those with textured microstructures, solid solutions (alloying), and/or chemically doped variants that capitalize on the ability to tailor defect populations and/or material properties along specific directions, it would facilitate production of MAX phase components (e.g., via powder compaction and densification or additive manufacturing) for the market that exploit their unique properties, particularly their operation in high temperature, neutron radiation, oxidizing, or corrosive environments or other harsh industrial applications.

For Phase I, this subtopic seeks proposals for low-cost, scalable powder synthetic routes or powder fabrication methods for high-purity MAX phases that have improved stability in harsh environments, as validated by appropriate materials characterization techniques and materials properties measurements.

Questions – Contact: J. Nick Lalena Nick.Lalena@ee.doe.gov, and Jeremy Mehta, Jeremy.Mehta@ee.doe.gov

d. Atomically Precise, Solid-state Devices for Energy Efficient Quantum Computing.

AMMTO's Atomically Precise Manufacturing effort and its EES2 R&D Roadmapping process [1, 2] have identified opportunities for quantum computers and quantum computing to contribute significantly to the EES2 goal of increasing microelectronics energy efficiency one thousand fold in the next 20 years. Since 2020, AMMTO has deployed a "physics-based" type of APM based on hydrogen depassivation lithography (HDL) [3,4] for a wide variety ultra-energy-efficient CMOS-compatible device nano-electronics devices. By making atomically precise patterns of both donor and acceptor dopants these devices can be engineered to be extremely high efficiency as the currents can be restricted to extremely low values and very modest voltages. By initiating this research, AMMTO hopes to accelerate advancements in energy-efficient, solid-state quantum devices. For example, AMMTO hopes that the initial Phase I research proof of concept results will lead to partnerships within DOE [5] and with other federal agencies including the NSF [6] to scale these innovations rapidly. AMMTO also notes that industry is beginning to make its own investments as the first new quantum products are identified and brought to market.

Single dopant atoms placed with atomic precision in a Si crystal can function as spin qubits. Fabrication of the first solid-state two-qubit gate using a scanning tunnelling microscope (STM) was first reported in 2018 [7,8]. Such two-qubit devices formed using HDL are the building blocks, –the quantum devices—that enable extremely energy efficient solid-state quantum computers.

Researchers have been able to demonstrate exquisite control over high-fidelity sequential readout of these two electron spin qubits [9]. This particular fabrication method begins with a p-type silicon substrate passivated with a single layer of hydrogen atoms. The STM tip is then used to desorb H atoms to make an atomically precise pattern of the device. The substrate is then exposed to gaseous PH_3 precursor. The H atoms left on the surface prevent the PH_3 molecules from being adsorbed so that it only is absorbed and incorporated on the exposed silicon pattern. [10] Finally, to protect the device by burying it in silicon, molecular beam epitaxy is used to grow a few nanometers of silicon on it. After the burial, prepatterned alignment marks are used to locate the device on the substrate so ohmic contacts can be made. In addition to bench-scale readout of the qubit device, researchers also have reported. Note in addition to spin qubits based on using electron spin in one or more donor atoms, spin qubits also can use: hole spin in one or more acceptor; spin in one or more donor atoms; and spin in one or more acceptor atoms.

In addition, fabrication of atomic-scale ultrathin Si:P nanowires with the lowest electrical noise (and hence highest efficiency) to connect to those qubits [11]. The same fabrication techniques create the gates that are used to set the spins on the qubits, control the interactions (entanglement) of the qubits, and fabricate the single electron transistors that read out the results (spin up or down) of the quantum computations.

For Phase I, this subtopic seeks proposals for appropriate solid-state qubit (e.g., quantum dot qubit), contact and interconnect characteristics and the characterization to verify these characteristics that will support the development of a prototype quantum device in Phase II.

Example Metrics for Subtopic c

Parameter	**Target**	**Stretch Target**
Quantum Device Design Energy Efficiency Improvement	3X	10X
Increased robustness of qubit design (e.g., variation in each qubit energy level is less than the energy difference between 0 and 1 state)	Variation in energy level < energy of +1 state	Variation in energy level 3x < than energy of +1 state

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

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C58-12. INDUSTRIAL EFFICIENCY AND DECARBONIZATION OFFICE (IEDO)

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
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

The U.S. Department of Energy’s (DOE) Industrial Efficiency and Decarbonization Office (IEDO) is working to build an efficient and competitive U.S. industrial sector with net-zero greenhouse gas emissions by 2050 [1]. IEDO provides funding, management, and the strategic direction necessary for a balanced national program of research, development, and demonstration (RD&D), as well as technical assistance and workforce development, to drive improvements in energy, materials, and production efficiency and to accelerate decarbonization across the industrial sector. IEDO’s RD&D strategy focuses on two complementary approaches: tackling subsector-specific decarbonization challenges in energy- and emissions-intensive industries and pursuing cross-sector challenges that are common across many industries.

This topic focuses on disruptive industrial innovations, including RD&D, small-scale demonstrations, and technology partnerships to drive U.S. industrial decarbonization, productivity, and economic competitiveness.

All applications to this topic must:

- Clearly indicate the subtopic and area of interest;

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- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions using appropriate metrics, key performance parameters, or properties as well as justify all performance claims with theoretical predictions and/or relevant experimental data;
- The program should include quantitative technical milestones, timelines, and expected deliverables that demonstrate aggressive but achievable progress toward meeting performance parameter targets;
- Provide evidence that the applicant has relevant experience and capability to successfully accomplish the proposed scope within proposed schedule and budget;
- Explain a project's output potential for future commercialization including projections for cost and/or performance improvements that are tied to a clearly defined baseline.

The Phase I application should detail material, design and/or lab-scale systems that are scalable to a subsequent Phase II prototype development.

Applications must be responsive to the following subtopics:

a. Enabling Industrial Grid Interactivity

Industrial electrification combined with the use of clean electricity is a key strategy for decarbonizing the industrial sector [2,3]. However, increased electrification across the economy (including the transportation, buildings, and industrial sectors) combined with increased generation from variable renewable energy may lead to significant impacts across the energy system. Newly electrified loads that can operate flexibly and that can provide grid services have the potential to ease this transition by increasing operational efficiency of the electric grid [4].

Traditional demand response programs have seen limited participation from industry due to weak incentives and the continuous and complex nature of many industrial operations. Many manufacturing facilities that currently participate in peak shaving programs often limit their flexible capabilities to less-critical, lower energy-intensity, and/or time-flexible process loads such as HVAC. However, the industrial sector has the potential to realize emissions and economic benefits by modulating energy consumption and optimizing the use of onsite and offsite resources, especially as facilities adopt clean onsite energy sources and energy storage technologies. Few core industrial processes are currently flexible, but to realize a widely electrified industrial sector, many more industrial processes will need to be adapted to enable flexible operation.
For this subtopic, IEDO seeks controls-based solutions, including integrated systems of advanced sensors, controls, data platforms, and industrial energy resources, to enable industrial load flexibility and grid interactivity. Industrial energy resources with capacity to enable flexible operations include onsite generation (e.g., CHP, renewables) and storage, plant utilities (e.g., compressed air), flexible industrial processes (e.g., cold storage, batch processes), and transportation (e.g., electric forklifts, electric transportation refrigeration units) [5]. Projects are encouraged to consider a diverse collection of such energy resources, but the project scope must include flexible industrial processes. Applications must demonstrate an increased capability for flexibility in energy usage compared to the state of the art.

Innovations under this subtopic may enable industrial facilities to:

- Reduce emissions, costs, and downtime through forward-looking and/or real-time adjustments to operations in response to price volatility, generation mix, and other parameters from the grid;
- Operate as "virtual batteries" to capitalize on the enormous amounts of energy used in the industrial sector to increase resilience and provide value-added ancillary services;
- Minimize impacts of outages, including loss of production, reduced product quality, damage to equipment, and long start-up times;

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- Manage and proactively shape peak loads, dynamically manage two-way power flows, and dynamically manage, control, and adjust to load and frequency variations; and
- Remain resilient and economically competitive as clean energy resources are integrated into industrial energy usage.

Table 1. Requirements for Technologies in Subtopic a

Objective/Goal	Metric	Target	Baseline
Enable increased flexibility	% energy usage around baseline	±30%	*Applicant defined*

Additional targets and metrics appropriate to the project should be included. Possible metrics include, but are not limited to: reduce unplanned downtime, reduce emissions intensity, reduce operating expenses, increase productivity, and reduce peak load.

Questions – Contact: Yaroslav Chudnovsky, yaroslav.chudnovsky@ee.doe.gov

b. Energy Efficient Gas Separations

This subtopic is focused on the advancement of manufacturing processes that can produce membranes with exceptional selectivity for separation of gas mixtures. The focus is on the high precision of the pores, which can allow extreme reduction in membrane thickness and low pressures—not on approaches that rely on tortuosity through randomly arranged small constrictions.

High selectivity membranes offer the potential to provide game-changing process energy advances. For example, thin molecular sieves can, in principle, separate air into its raw components of N_2, O_2, H_2O, Ar, CO_2, Ne, He, etc. for significant energy savings in a wide range of chemical and combustion processes [6-10], heating and air conditioning, and for concentrating CO_2 for efficient carbon capture. Another example is the purification and separation of He from natural gas for energy efficient, low-cost production of this strategic resource [11].

In this subtopic, IEDO seeks grant applications to advance scalable technologies that provide substantial improvements in the selectivity and permeance of current industrial gas separations. Additional consideration should be given to addressing the following barriers: fouling resistance, chemical stability, durability, substrate material, and cost. The choice of membrane material should be appropriate to the target separation in a commercial setting. Target separations with high energy impact are preferred. For example, the separation of water from air could provide ultra-dry air for drying applications at reduced temperature and cooling applications at reduced energy consumption. Applications must demonstrate progress in Phase I and achievement in Phase II of the following performance and cost targets:

Requirements	Baseline
50% improvement in selectivity	Best in class commercial membrane for the target application
50% improvement in permeance	Best in class commercial membrane for the target application

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As a deliverable, a 50% improvement in selectivity and 50% improvement in permeance over an equivalent separation in current commercial practice shall be demonstrated through the synthesis and testing of target membranes, with sufficient experimental measurements and supporting calculations to show that cost-competitive energy savings can be achieved with practical economies of scale. The applicant's technology may also be benchmarked against, for example, a rival non-membrane technology such as pressure swing absorption or cryogenic separation if there is no comparable gas membrane separation benchmark. The application should provide a path to scale up in potential Phase II follow on work.

Not of interest for this subtopic: Fundamental studies and pure academic investigations (especially for the graphene-based, zeolites and metallic oxides types) are not of primary interest to this subtopic. The applicants should provide a strong argument and justification for commercial relevance of their proposed concept.

Questions – Contact: Yaroslav Chudnovsky, yaroslav.chudnovsky@ee.doe.gov

c. Innovations in Heat Exchange Processes, Equipment, and Integration Approaches for Deep Waste Heat Recovery

Thermal energy losses (in the form of sensible and latent heat) generated by industrial processes can be reused for preheating, cogeneration, cooling and refrigeration services, products drying, etc. For this subtopic, IEDO seeks innovative concepts, designs, or industrial solutions aimed at significantly improving the recovery of waste heat (WHR) generated by industrial operations. Proposed technologies include, but are not limited to, innovations in heat transfer enhancement techniques and thermal-driven (waste heat to power) technologies, novel types of heat exchange equipment and integration approaches for a wide spectrum of industrial systems to achieve significant energy savings and carbon footprint reduction. Innovative heat exchange processes cost-effectively employed into industrial WHR systems can lead to reduced energy consumption, compactness, and easier integration into existing industrial operations. State-of-the-art technologies for WHR include recuperators, regenerators, preheaters, waste heat boilers, cogeneration systems, etc., and typically combine various types of heat exchangers or thermal energy conversion components [12]. Non-metallic thermal energy exchangers for low-temperature industrial exhausts (polymers, composites, other materials) are of special interest for this subtopic. Non-metallic heat exchangers show distinct advantages due to their light weight, manufacturing potential, wide range of geometric design possibilities, corrosion resistance, and potential to overall cost reduction.

This subtopic focuses on innovative processes, equipment, and integration approaches to provide deep WHR in industrial processes by efficiently and cost-effectively recovering both sensible and latent heat to achieve the targets below (Table 2).

Table 2. Requirements for Innovative WHR Technologies for Subtopic c

Requirements	Targets
Waste heat recovery rate (reference point – relevant ambient conditions)	at least 75% for heat source < 450°F at least 85% for heat source > 450°F
Temperature of recovered exhaust gas	< 5°C above ambient temperature, stretch target – below ambient temperature
Cost	Should be competitive or better with state-of-the-art technologies
Waste heat to power electric efficiency	> 40% for heat source < 450°F > 60% for heat source > 450°F

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Not of interest for this subtopic: Heat pump systems and their components, combined cycles, and supercritical CO_2 power cycle are not of primary interest for this subtopic.

Questions – Contact: Yaroslav Chudnovsky, yaroslav.chudnovsky@ee.doe.gov

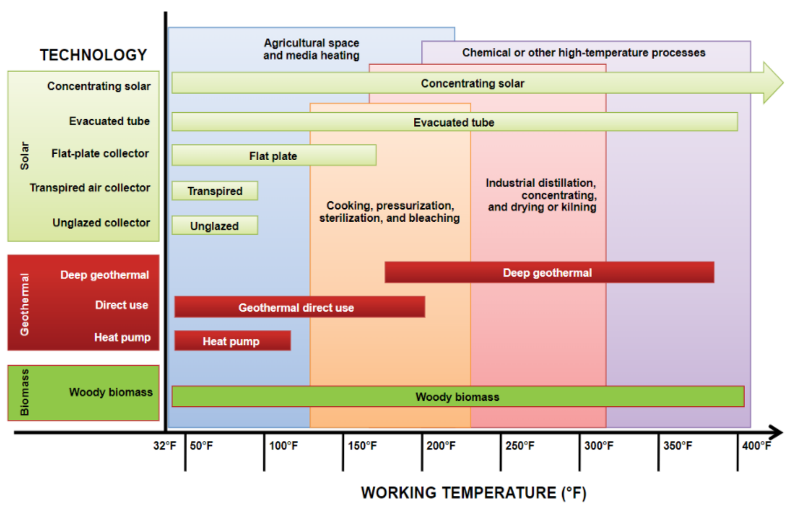
d. Renewable Hybridization of the Industrial Processes

For this subtopic, IEDO seeks original innovative solutions on renewable energy assistance to decarbonize U.S. industry. Special interest is in fully integrated technological concepts that can provide a high impact (non-incremental) to industrial operations in terms of energy efficiency improvement and carbon footprint reduction. The proposed solutions must be cost-effective with a simple payback as indicated in the table below.

The U.S. industrial sector uses heat for a wide variety of applications, including washing, cooking, sterilizing, drying, preheating of boiler feed water, process heating, and much more. Altogether, estimates show the industrial sector uses more than 24 quadrillion Btu, or roughly one-third of the nation's delivered energy supply [13].

Industrial applications require different temperature ranges, quantities, and rates of thermal energy. Hybrid solutions and thermal energy storage would play an important role for dispatching heat at optimal times needed by the industrial application demand [14].

Energy input from renewable sources (e.g., solar, wind, geothermal, biomass, and others) can replace fossil fuels in a wide variety of industrial applications, including chemical production and petroleum refining, iron and steel, cement, papermaking and the food and beverage industries, which account for 15% of the U.S. economy's total carbon emissions.



Many renewable resources can easily meet the lower thermal requirements. However, if renewable sources cannot support the entire heating load, they can still provide pre-heating to supplement a conventional heating process. In some industrial applications even a modest amount of pre-heating or energy offset can reduce a site's dependence on fossil fuels or grid electricity. For example, waste heat from a high-temperature industrial process can possibly support another process requiring a lower temperature. Chemical processing, kilning, drying, curing, sterilization, and distillation activities requiring higher temperatures can use evacuated tube solar collectors, direct use geothermal water, or biomass furnaces. Chart [15] illustrates the state-of-the-art renewable technologies and corresponding applications depending on the process temperature range.

Renewable assistance to energy- and emissions- intensive industrial applications can capitalize on existing infrastructure and add components to help reduce costs, environmental impacts, and system disruptions.

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Requirements	Target	Stretch
Energy consumption reduced by	> 30%	> 50%
Simple payback	10 years	5 years or better

Not of interest for this subtopic: Hybrid energy systems using small modular nuclear reactors are not of particular interest for this subtopic.

Questions – Contact: Yaroslav Chudnovsky, yaroslav.chudnovsky@ee.doe.gov

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C58-13. BIOENERGY TECHNOLOGIES

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

The Bioenergy Technologies Office (BETO) advances technologies that convert domestic biomass and other waste resources into cost effective, low-carbon biofuels and bioproducts. These technologies hold the promise of enabling a transition to a clean energy economy, creating high-quality jobs, supporting rural economies, and spurring innovation in renewable energy and chemicals production as part of the bioeconomy.

Grant applications are sought in the following subtopics:

a. Sustainable Biomass Conversion to Bio-based Materials

BETO supports efforts to decarbonize the industrial sector to produce cost-effective and sustainable chemicals, materials, and processes utilizing biomass and waste resources. Specifically, the Bioenergy Technologies Office has a goal to enable commercial production of >10 renewable chemicals and materials with >70% GHG reduction compared to petroleum-derived counterparts. Many incumbent materials and durable goods pose sustainability challenges including the use of hazardous chemicals during manufacturing, reliance on fossil fuel feedstocks, and do not consider end-of-life fate. Regulations are emerging in the United States and worldwide that necessitate sustainable replacements to commonly used materials such as foams, adhesives, resins, and others.

This topic is focused on converting sustainable biomass and waste feedstocks to bio-based materials. Applicants should refer to the topic requirements below for allowable feedstocks. Biochemical, chemical, and electro catalysis conversion processes are eligible to apply that utilize either bio-derived intermediates (e.g. cellulosic sugars, lignin, bio-oils) or minimally processed biomass (e.g. biorefinery lignin, cellulose). In addition, processes for purification or recovery of biomaterials are eligible to apply, recognizing that product separations are a significant economic and sustainability driver.

Specific bio-based materials of interest include (but are not limited to):

- Carbon fiber
- Structural or composite materials – including nano-cellulose
- Textiles
- Foams – including non-isocyanate polyurethane
- Polycarbonates- including BPA replacements
- Adhesives
- Filtration/membrane replacements
- Epoxy resins

Particular research areas of interest for this topic could include (but is not limited to):

- Development of biochemical, chemical, and/or electrochemical methods for producing bio-based materials or precursors
- Characterization of bio-based intermediates (e.g. lignin, cellulose) for use in the applications above

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- Separation techniques that have low energy inputs and achieve high yields of compounds for use in the above applications
- Performance testing and evaluation of relevant material properties such as tensile strength, flexural strength, water permeability, thermal conductivity/resistance, biodegradability, etc.
- Advancing and scaling up of approaches that produce biomass derivatives suitable for bio-based materials (e.g. reductive catalytic fractionation of lignin)
- Refinement of TEA or LCA of the proposed process

Topic Requirements:

- The bio-based material must be derived from one of the following feedstocks:
- Lignocellulosic biomass (such as corn stover, forestry residues, paper/pulp residues)
- Energy crops (such as energy cane, switchgrass)
- Organic waste (such as food waste, municipal wastewater sludge, animal manure, or biogas derived from the above)
- Non-recyclable fractions of municipal solid waste (such as material recovery facility residues)
- Micro- or macro-algae
- Chosen bio-based materials must have a significant potential market size and must quantify the market size in their application.
- As part of the application, applicants should include a preliminary TEA. A preliminary LCA is encouraged, but not required at the time of application. In order to be eligible for phase 2, LCA must show a GHG savings of >70% relative to petroleum incumbent or counterpart molecules
- By the end of phase 1, the project must have tested real biomass or waste streams in the conversion process being developed.
- Processes must exhibit the potential to be scaled up to pilot- or demonstration-scale

Specific areas not of interest:

- Projects proposing the production of pharmaceuticals, bio-based materials for medical devices, nutraceuticals, or specialty chemicals
- Projects that exclusively use CO2 as a feedstock
- Projects that propose starch sugar as a feedstock
- Projects proposing alternative feed or feed proteins as end products

Questions – Contact: Beau Hoffman, Beau.Hoffman@ee.doe.gov

b. Alternative Uses of Commercial Equipment (ACE)

As part of the Government's comprehensive strategy to decarbonize all modes of transportation, BETO is primarily focused on RD&D to produce "drop-in" biofuels from renewable biomass and waste resources that are compatible with existing fueling infrastructure and difficult-to-electrify modes of transportation including aviation, maritime, rail, and medium-to-heavy duty off-road vehicles. This multi-faceted approach is part of the Administration's strategy to spur the development of homegrown renewable biofuels, which is critical to expanding Americans' options for affordable fuel in the short-term and to building real energy independence in the medium- to long-term by reducing our reliance on fossil fuels.

One of the major barriers to deploying new low-carbon based biofuel pathways is the efficient preprocessing of the starting biomass feedstocks to ensure it can easily, and relatively inexpensively, be biologically or thermochemically converted into biofuels, co-products, and biointermediates. While progress had been made

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on preprocessing unit operations, such as hammer and knife mills, new feedstocks are entering the R&D pipeline that may require new preprocessing methods to meet the specifications of the conversion process. Rather than developing new equipment, the intent of this topic is to test commercially available equipment, with minor or major modifications, to demonstrate preprocessing of biomass and waste feedstocks.

Target preprocessing specification metrics could include, but are not limited to:

- Size reduction
- Particle size distribution
- Contaminant removal (inorganics)
- Moisture content
- Densification
- Extraction (oils, starch, etc.)

Phase 1 Topic Requirements: projects should identify at least one commercially available piece of equipment they wish to test and/or modify, source at least two acceptable feedstocks (see below) that can be processed by the equipment and demonstrate at least three target preprocessing specifications that the equipment could meet for downstream conversion users. Stretch goal: modification of the equipment, initial preprocessing runs, and trail conversion to bio-intermediates.

Special attention should be made for reducing and analyzing wear (erosion and/or corrosion) in the equipment. Historically, biomass has shown to rapidly degrade equipment such as screw augers given the recalcitrant nature of the feedstocks. Promising unit operations would ideally be developed and tested at larger scales under a Phase 2 award for adoption by biomass conversion technology providers and/or equipment manufactures.

Allowable Feedstocks: Agriculture residues (corn stover, bagasse, etc.), energy crops, algae, organic wet wastes (food waste, sewer sludge, etc.), sorted non-recyclable municipal solid waste, construction and demolition debris, and oilseeds (all parts of the seed).

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

C58-14. BUILDING TECHNOLOGIES

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

DOE's Building Technologies Office (BTO) (http://energy.gov/eere/buildings) is working in partnership with industry, academia, national laboratories, and other stakeholders to develop innovative, cost-effective, energy saving technologies that could lead to a significant reduction in building energy consumption and enable interactions between buildings and the power grid. The rapid development of next-generation building technologies are vital to advance building systems and components that are cost-competitive in the market, to enable deep energy use reduction and lead to the creation of new business and industries.

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

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

- Include projections for cost and/or performance improvements that are tied to clearly defined baseline and/or state of the art products or practices.
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions.
- Include an estimate of energy savings and/or demand flexibility impact as well as a preliminary cost analysis.
- Justify all performance claims with theoretical predictions and/or experimental data.

All successful applications 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 to establish the technical merit, feasibility, proof of principle, and commercial potential of the proposed approach. The objective of Phase II is to continue the efforts initiated in Phase I. Funding is based on the results achieved in Phase I. The fundamental question of penultimate price and performance of the proposed innovation should be well documented and clear in the Phase II application. Only Phase I awardees are eligible for a Phase II award.

BTO seeks applications in the following subtopics:

a. Windows

Windows are responsible for over 3 quads of energy loss, and there is the potential for passive energy and daylight harvesting that brings the energy impact to over 4 quads. The IECC 2021 residential building codes have made significant progress on the opaque envelope, with walls requiring R30 and roofs R60 performance, yet windows are only around R3.3. In a typical home being built to the IECC 2021 requirement in a cold climate, windows represent approximately 45% of the thermal loss but only 8% of the surface area of the home. Recent DOE R&D success has achieved innovative thin-triple pane windows that are now commercialized by multiple manufacturers, and market transformation of these products are on the cusp of wide-spread market adoption through the issuance of the ENERGY STAR v7 criteria (R4.5) that DOE and LBNL played a key role in supporting EPA. However, a major gap exists between market viable R5 windows and the R13 residential and R10 commercial goals published in the Research and Development Opportunity (RDO) Report – Pathway to Zero Energy Windows[1]. The following topics are aimed at removing key barriers to improve window performance and to reduce cost, along with tools that are focused on making window replacement more viable.

1) Highly Insulating Windows
DOE is interested in core technologies, materials developments, and process development that can contribute to major improvement in the cost-effective improvement in window thermal performance. The following list of examples is illustrative but not exhaustive, key principles to be successful in this topic are that they must have the potential to make significant improvement in performance and have the potential for wide market applicability and adoption and have the potential to achieve the RDO cost and performance targets.

a) Highly durable hermeticity sealed glass to metal bonding with low thermal conductivity for improved edge performance in vacuum insulated glass, b) low cost krypton extraction and filling, c) low cost remote sensing of SHGC of existing fixed and operable windows, and frame and glass thermal performance, d) innovative spacer designs that accommodate two center lites with only having two seals in quad pane insulated glazing units, e) thermal frame caps for use with secondary window/glazing systems and can reduce the thermal loss of vacuum glazings, f) low conductive infill materials, etc.

2) Dynamic Solar Control

Integration of dynamic solar control systems, e.g. shading and electrochromic glazings have been demonstrated to reduce peak electricity demand by 25% or more, and can provide passive heating contributions and dramatic reductions in cooling leading to zero energy windows (windows that do not have any annual energy loss compared to a building without windows) with existing building infrastructure. While core material development of electrochromic materials, transparent PV generating windows, and other advanced material development is not within scope of this subtopic, the effort involves the control function with low-cost devices that are extremely easy to install. A core goal is to eliminate the need to wire window systems to communication and power sources, thus wireless systems are essential but they also must be able to communicate with a large array of existing components that are used in current dynamic façade systems such as occupancy sensors, actuators, thermostats, lighting controls, etc.

Questions – Contact: Marc LaFrance, Marc.LaFrance@ee.doe.gov

b. Affordable TES Systems

Thermally driven loads make up over 53% of primary energy used in buildings, contribute to over 55% of all CO2 emissions, and are among the primary drivers of peak loads in the building sector. Thermal Energy Storage (TES) can play a significant role in shifting and shedding building loads while facilitating space and water heating electrification and building and grid decarbonization.

BTO seeks the development, validation, and commercialization of next generation TES technologies to facilitate heating electrification, building decarbonization, and resilience. Key drivers in making TES systems economically viable are the costs to integrate thermal storage with equipment (HVAC, hot water systems) and the envelope. These costs include storage materials, such as phase change materials, the heat exchanger, other systems components, packaging, and installation. This TES topic focuses on developing field installable plug-and-play TES systems with low integration cost, improved performance, and ease of installation to accelerate adoption of TES in space conditioning and hot water applications.

Examples include, but are not limited to:

- TES-heat pump systems with combined space heating and cooling, enhanced cold climate performance, and affordability over non-storage heat pump baseline.
- Easy to install thermal storage insulation systems that can be affordably integrated into existing building envelops, such as attics and walls, to manage the building's dynamic thermal response for enhanced thermal comfort, energy efficiency, and resilience (e.g., peak temperature reduction, shifts in peak load times, and moderating seasonal energy demands).
- Plug-and-play thermal storage solutions designed for replacing or retrofitting hot water systems that can be charged by heat pumps, help reduce space constraints, and potentially provide greater resilience than a traditional tank water heater.

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

c. Advanced Air Leakage Detection and Air Sealing Technologies

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Air leakage through the building envelope in the U.S. accounts for about 4 quads of energy annually, costing approximately $10 billion per year. In aggregate, infiltration accounted for higher energy losses than any other component of the building envelope, including fenestration. Improving airtightness is essential to meet the country's goal of becoming carbon-neutral by 2050.

More than 70% of the existing buildings were built before the first energy codes were enacted. While many of these buildings have some level of airtightness incorporated into their designs, there are still many buildings with no designed air control. The buildings from this era have air leakage levels two to ten times above what is required by the current energy code.

BTO seeks the development and validation of (1) higher fidelity, portable air leakage diagnostic technologies that can be used to identify the location and quantify the extent of infiltration/exfiltration in occupied buildings and (2) advanced air-sealing technologies designed specifically for use in existing, occupied building that can substantially reduce air sealing costs.

1) Fast, accurate, affordable, and portable air leakage detection technologies that identify the location and extent of leakage and could be widely used among different income groups. Technology should employ readily available, low-cost hand-held hardware (i.e., smart phone) and an easy-to-use app/interface to identify air leakages in residential and/or commercial buildings.
2) Advanced, cost-effective air-sealing retrofit technologies that are designed specifically for use in existing, occupied buildings and hard to remediate areas, such as attics, walls, finished basements, and crawlspaces. These air-sealing technologies and approaches should minimize or eliminate the need for envelope disassembly, and be easy, fast, and much more affordable to implement than traditional approaches. Productivity tools that aid workers to complete air-sealing jobs faster are also of interest.

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

d. Insulation Innovations

Almost all houses in the U.S. building stock would benefit from an insulation upgrade. 50-70% of energy usage in an average American home is associated with heating and cooling. Inadequate insulation and envelope leaks are the leading causes for of wasted energy. Older houses and commercial buildings can pay off the cost of an insulation upgrade within a few years through reduced utility bills. Insulation upgrades can also increase occupant comfort and provide a sound barrier.

Advanced insulation technologies can further improve the efficiency of the building envelope and increase the building's temperature uniformity (reducing hot/cold spots). To decrease heating and cooling energy load and associated costs used in buildings associated with heating and cooling costs, an advanced insulation solution would have a high R-value to improve thermal performance and be durable (mechanical, moisture, etc.), lightweight, and easy to install in any building retrofit or new construction project. Since almost all buildings can benefit from an insulation upgrade, advanced insulation solutions should be widespread and accessible to all homeowners and building owners.

This topic seeks the development of affordable, advanced insulation materials, systems, and installation tools. Examples include, but are not limited to:

- Insulation materials that are low-cost and ideally low-carbon, achieve a high-R-value per inch ≥ 8 at a $1.00 or less per square foot wholesale material cost, durable and have a 30+ year life expectancy in each climate zone and are non-flammable and non-toxic. The insulation material must be able to utilize manufacturing processes and input materials that are inherently scalable.

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- Super insulated R-value ≥ 25 wall retrofit panels that are fire-resistant and achieve an installed cost under $10 per square foot.
- Productivity tools for easier and higher quality installation.

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

e. Solid-State Lighting Technologies

This subtopic solicits R&D proposals for innovative solutions in advanced solid-state lighting technologies (SSL). There are three subtopic areas of interest for Lighting R&D. Please note that awards may not be made in all areas, and the distribution will depend on the number and quality of proposals received. In all cases, project benefits should be demonstrated and validated as part of the proposed project structure. A clear demonstration of product or technology capabilities is required for consideration for advancement to Phase II funding. For detailed information on these topics, applicants should refer to the 2022 Solid State Lighting Research and Development Opportunities document[1] and the 2022 DOE Solid State Lighting Manufacturing Status and Opportunities document[2].

1) Advanced Lighting Fixtures

The DOE seeks Advanced lighting fixtures with novel features for advancement of the Lighting Program objectives for energy savings, ultra-high efficiency, health benefits, robustness and resiliency, building integration, use of sustainable materials, and/or reduced ecological impacts. Example concepts include:

- form factors for improved building integration and light application efficiency;
- improved delivery of light levels that support health and wellbeing (daytime);
- use of more sustainable materials within the fixture;
- approaches that prevent and reduce light pollution;
- paradigm-shifting form factors and building connection approaches;
- color-mixed or hybrid light emitting diode (LED) arrangements for exceptional efficiency;
- improved resiliency through, e.g., highly durable fixtures, battery, or renewable energy-integrated systems, and/or advanced building integrations for continuous operation in adverse conditions.

Applicants should demonstrate clear innovation beyond simple integration of available components and should be able to define a convincing commercialization pathway.

2) Lighting for Controlled Indoor Agriculture

Advanced LED fixture designs with novel features for controlled environment agriculture or animal production lighting are desired. Proposals should emphasize unique features that optimize plant growth or animal well-being while maximizing energy savings and sustainable production. Applicants should demonstrate clear innovation beyond simple integration of available components and should outline an appealing commercialization pathway.

3) Germicidal Ultraviolet (GUV) Lighting Solutions

DOE seeks innovative GUV-LED lighting solutions that effectively neutralize harmful pathogens while ensuring safety and efficiency. Proposals should detail the technology's germicidal efficacy, energy efficiency, operational longevity, cost effectiveness, and potential applications in diverse settings[3,4].

Questions – Contact: Wyatt Merrill, Wyatt.Merrill@ee.doe.gov

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f. Heat Pumps/Heat Pump Water Heaters (HP/HPWH)

This subtopic solicits proposals for innovative solutions in heat pump technology and other supporting technologies. There are four subtopics focusing on heat pumps in cold climates, cost compression of heat pumps and heat pump water heaters, building integration of heat pumps and heat pump water heaters, and heat pump water heater-ready outdoor enclosures. Please note that awards may not be made in all areas, and the distribution will depend on the number and quality of proposals received.

All applications should provide metrics relevant to their proposals. These may include, but are not limited to, cost reduction, performance improvement, emissions reduction, size/weight reduction, power-reduction, and market scaling targets (with supporting information) that are in line with BTO's goals. All applications should also describe how their technology differs from existing commercially available technologies/solutions (and technologies already receiving federal support), describe how it advances the state of the art and provide rationale for why the applicant is qualified to carry out this work. Strong applicants may also provide letters of support from industry and community partners. Submissions accounting for the unique position of low-income occupants are strongly encouraged.

1) Heat Pump Systems for Cold Climates

Heat pump adoption is a major priority for BTO. In many locations there are challenges to adoption including but not limited to: efficiency/capacity degradation at lower temperatures, high electricity prices, misaligned replacement cycles between existing heating and AC systems, etc. A systems-based approach to heat pumps can allow for major decarbonization of space conditioning while creating solutions for some of these issues (for example, dual fuel systems that enable operation at very cold temperatures, controls for advanced cold climate heat pumps).

BTO is primarily interested in heat pump systems involving legacy systems (e.g. already installed furnaces) and they thus require complex installations as two technologies from different eras need to function together seamlessly. This requires well-designed equipment, controls that can integrate the use of the two separate systems in a way that provides continuous comfort to the occupant (and allow for users to prioritize their switchover temperature based on cost, carbon intensity, and/or other relevant metrics), and an installation process that isn't overly burdensome.

To better facilitate the uptake of heat pumps in cold climates, work must be done to address the following challenges:

- Creation of heat pump systems that physically fit in the available space and can be integrated seamlessly with the existing system,
- Improving the controls logic of heat pumps systems in cold climate, and
- Allowing for easier installation/set-up of the physical systems.

2) Cost Compression of Heat Pumps and Heat Pump Water Heaters Systems

Heat pump adoption is a major priority for BTO. Our research and broad stakeholder engagement has identified heat pump and heat pump water heater (HP/HPWH) system price reductions as one of the largest opportunities in this space, especially in cold climates. These reductions can be found in a variety of places throughout the HP/HPWH lifespan including, but not limited to, the improvement of components, the system assembly/design, the distribution, and the installation. All submissions are expected to (when relevant) minimize the global warming potential (GWP) of the associated refrigerant. Preference will be given to projects at or below 150 GWP.

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To realize the necessary, broad adoption of HP/HPWHs required to achieve BTO's goals, work must be done to reduce costs in the following areas:

- System assembly/design spanning all types (including portable units, window units, mini splits, central systems, integrated/packaged and stand-alone/modular thermal energy storage systems, etc.) and heating mediums (air-to-air, air-to-water, ground source, etc.);
- Distribution, including transportation and enhanced communication between major players (manufacturers, suppliers, distributors, big box retailers, contractors, and others not listed); and
- Installation, including all system designs identified earlier and adjacent, connected equipment, and contractor training.

3) Building Integration of Heat Pumps and Heat Pump Water Heater Systems

Heat pump adoption is a major priority for BTO. Our research and broad stakeholder engagement has identified improving building integration with heat pumps and heat pump water heaters (HP/HPWH) as one of the largest opportunities in this space. Space and water heating systems interact with many aspects of a building and ensuring smooth, coordinated interactions is key to realizing positive outcomes during broad heat pump deployment.

To realize the necessary, broad adoption of HP/HPWHs required to achieve BTO's goals, work must be done in the following areas:

- Facilitating smooth, coordinated retrofit sequencing incorporating the relative ages, costs, and available discounts of equipment;
- Providing actionable information regarding the interactions between equipment selection/sizing and envelope performance, including the creation of mechanisms to allow for emergency replacements of equipment without losing load reduction opportunities; and
- Providing alternative options to standard electrical panel upgrades, especially lower-cost versions.

4) Heat Pump Water Heater-Ready Outdoor Enclosure

In certain locations in the US (particularly in the Southeast), many water heaters are located outdoors. For conventional water heaters and heat pump water heaters (HPWHs) with electric resistance back-up, this is rarely an issue. However, preliminary research into 120V HPWHs without electric resistance back-up has shown that in the coldest months of the year, it's possible for there to be sustained temperatures below the compressor lock-out temp. As weather becomes more variable in our warming climate, instances of these sustained cold temperatures may occur more often. In order to avoid hot water run outs on these days, while still avoiding electrical panel upgrades through the use of low-power appliances, BTO is interested in the commercialization of a heat pump water heater-ready outdoor enclosure.

To achieve maximum usability, an ideal enclosure would have the following characteristics:

- Availability in two sizes: 30 in x 74 in x 30 in and 36 in x 84 in x 36 in,
- Built-in vent termination and ducting,
- Built-in connections for a 250 W heating rod (with 50%, 75%, and 100% settings) at the top of the enclosure,
- Built-in condensate drain line with heat trace,
- A single 120V cord and plug to power heating rod and heat trace (15 ft cord),
- Connections along the bottom for an attachable rubber mat for the enclosure floor, which is included as sold, and
- A bottom grill on the enclosure door (12 in x 4 in), approximately 10 inches from the enclosure floor.

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Questions – Contact: Alexander Rees, Alexander.Rees@ee.doe.gov

References: Subtopic a:

1. Harris, C., 2022, Advancing Technologies and Market Adoption, Pathway to Zero Energy Windows https://www.nrel.gov/docs/fy22osti/80171.pdf

References: Subtopic e:

1. Pattinson, M., et al, 2022, 2022 Solid-State Lighting R&D Opportunities https://www.energy.gov/sites/default/files/2022-02/2022-ssl-rd-opportunities.pdf
2. Hansen, M., et al, 2022, DOE BTO Solid-State Lighting Program, "2020 DOE SSL Manufacturing Status & Opportunities", https://www.energy.gov/sites/default/files/2022-02/2022-ssl-manufacturing-status-opportunities_0.pdf
3. Tuenge, J., Arnold, G., et al., 2023, Radiometric Testing of Germicidal UV Products, Round 1: UV-C Towers and Whole-Room Luminaires, CALiPER Full Report, Office of EERE, PNNL-33824, https://www.energy.gov/sites/default/files/2023-09/ssl_caliper-guv-rd1-full.pdf (October 20, 2023)
4. Davis, L.J., Rountree, K., et al, 2022, Operating Lifetime Study of Ultraviolet (UV) Light-Emitting Diode (LED) Products, U.S. Department of Energy—Lighting R&D Program, https://www.energy.gov/sites/default/files/2022-09/ssl-rti_uv-leds-lifetime_apr2022.pdf

C58-15. 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
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

Geothermal energy is secure, reliable, flexible, and constant. It continues to be one of America's best choices for low-cost renewable energy in power generation and in direct-use applications for heating and cooling of American homes and businesses. The Geothermal Technologies Office (GTO) focuses on applied research, development, and innovations that will improve the competitiveness of geothermal energy and support the continued expansion of the geothermal industry across the U.S. [1]. Specifically, GTO is focused on significantly increasing geothermal electricity generation and the use of geothermal heat pumps and district heating by 2050 [2].

A Phase I application should focus on proof of concept and/or bench scale testing that are scalable to a subsequent Phase II prototype development/deployment. Applications must be responsive to the subtopic below. Any application outside of this area will not be considered.

Applications must:

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

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Grant applications are sought in the following subtopic:

a. Advanced Data Collection for Geothermal Exploration

GTO seeks applications for projects that will accelerate collection of requisite high-value datasets that justify investments in exploratory drilling, one of the higher risk phases of geothermal development. The primary research objective is to demonstrate significant improvements in survey cost, efficiency, speed, and/or scale compared to current practice for several commonly used methods to indicate potential high-temperature geothermal reservoirs. Secondarily, projects will supply needed data to validate ongoing resource assessment efforts and support development of a geothermal resource playbook [3].

The following processes are of particular interest:

- remotely characterizing permeability using passive seismic emission tomography (PSET);
- identifying anomalous heat flow via shallow temperature measurements;
- mapping structures via combined potential fields and electromagnetic surveys;
- mapping hydrothermal mineral occurrences via spectral signature;
- chemical/isotope sampling.

It is anticipated that multiple pathways exist toward substantially accelerating the collection of field data as described above. Examples include but are not limited to:

- improvements in instrument sensitivity, resolution, size, unit cost, endurance, depth of interrogation, etc.;
- deployment of mobile sensor platforms (surface, air, or space-based);
- autonomous surveys conducted beyond the operator's visual line of sight (BVLOS);
- robotic deployment and retrieval of sensor nodes, shallow emplacement of sensors, and wireless communicating sensor nodes;
- reduction of environmental impacts to simplify or obviate permitting requirements.

Applications must be responsive to the subtopic of improving the collection of high-value datasets for the purposes of geothermal exploratory drilling. Applications focusing on collection of data via traditional technologies or gathering of data that is not of interest under this subtopic will be deemed non-responsive.

Questions – Contacts: Michael Weathers, michael.weathers@ee.doe.gov or William Vandermeer, william.vandermeer@ee.doe.gov

References:

1. Geothermal Technologies Office, 2023, Geothermal Technologies Office, Office of Energy Efficiency & Renewable Energy https://energy.gov/eere/geothermal (October 18, 2023)
2. U.S. Department of Energy, 2023, Geothermal Technologies Office, GeoVision, https://www.energy.gov/eere/geothermal/geovision (October 18, 2023)
3. Ayling, B. and Faulds, J., et al, 2023, INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems (INGENIOUS) project, Great Basin Center for Geothermal Energy, https://gbcge.org/current-projects/ingenious/ (October 18, 2023)

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C58-16. HYDROGEN AND FUEL CELL TECHNOLOGIES

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

The Hydrogen and Fuel Cell Technologies Office (HFTO) (https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office) is part of DOE's comprehensive energy portfolio aimed at building a sustainable energy economy and addressing the climate crisis, which is a top priority of the Biden Administration. The goals are to achieve carbon pollution-free electricity by 2035 and to "deliver an equitable, clean energy future, and put the United States on a path to achieve net-zero emissions, economy-wide, by no later than 2050" [2] to the benefit of all Americans.

The activities to be funded by HFTO will support the goals of DOE's Hydrogen Shot[3], which targets affordable clean hydrogen production at $1/kg within the decade, and the H2@Scale Initiative[4], which aims to advance affordable hydrogen production, transport, storage, and utilization to enable decarbonization and revenue opportunities across multiple sectors.

Additionally, activities to be funded by HFTO and the Office of Clean Energy Demonstrations (OCED) will address the new clean hydrogen provisions of the November 2021 Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law (BIL). It includes provisions for the investment by DOE of $9.5 billion over 5 years in the research, development and demonstration of clean hydrogen production, storage, distribution, and end use technologies. Section 40314 includes $8 billion for establishment of at least four Regional Clean Hydrogen Hubs, $500 million for Clean Hydrogen Technology Manufacturing and Recycling, and $1 billion for Clean Hydrogen Electrolysis Program.[5]

Applications are sought to address the overarching HFTO program goal of facilitating wide-spread adoption of hydrogen and fuel cells across sectors by reducing the cost and improving the performance and durability of fuel cells, as well as developing affordable and efficient technologies for hydrogen production, delivery, and storage. The scope is technology-neutral and feedstock-flexible, emphasizing diverse end uses including energy storage (e.g., reversible fuel cells), transportation (e.g., trucks, marine, rail, mining), backup power (e.g., emergency power, data centers), chemicals production (e.g., ammonia, synthetic fuels), industry (e.g., iron and steel making), and others.

Applications submitted to any of these subtopics must:
- Propose a tightly structured program including technical milestones that demonstrate clear progress, are aggressive but achievable, and are quantitative
- Include projections for performance and/or cost improvements that are tied to a baseline
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions

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[2] Executive Order 14008, "Tackling the Climate Crisis at Home and Abroad," January 27, 2021.
[2] Hydrogen Shot | Department of Energy, https://www.energy.gov/eere/fuelcells/hydrogen-shot
[3] H2@Scale | Department of Energy, https://www.energy.gov/eere/fuelcells/h2scale
[4] H2IQ webinar presentation "DOE Update on Hydrogen Shot, RFI Results, and Summary of Hydrogen Provisions in the Bipartisan Infrastructure Law," December 8, 2021, https://www.energy.gov/sites/default/files/2021-12/h2iq-12082021.pdf

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- Include a preliminary cost analysis and justify all performance claims with theoretical predictions and/or relevant experimental data

HFTO seeks applications in the following subtopics:
- Novel Applications for Stationary Fuel Cell Systems
- Novel Materials for Use in Liquid Hydrogen Service
- Novel Concepts for Hydrogen Infrastructure and Storage
- Power Take-off Units for Medium-Duty Fuel Cell Electric Vehicles

BIL Funded
- High Temperature Membranes and Membrane-Electrode Assemblies for Fuel Cell Operation
- Advanced Proton Exchange Membrane (PEM) Electrolyzer Bipolar Plates
- Novel Water Electrolyzer Concepts

a. Novel Applications for Stationary Fuel Cell Systems

This subtopic solicits applications for novel stationary fuel cell applications that will meet end-user needs, enable new markets for fuel cells, lead to increased demand, and support hydrogen infrastructure development.

Fuel cells have benefits in diverse applications across multiple sectors including transportation, stationary power generation, and industrial uses. For stationary applications in particular, fuel cells offer high reliability, resiliency, fuel flexibility, and efficiencies for distributed power and long-duration energy storage applications, with overall efficiencies exceeding 80% when fuel cells are used in combined heat and power applications. Fuel flexibility is an added benefit, as fuel cell technologies can operate on a variety of primary fuels including bio-derived fuels. Fuel cells have been demonstrated in primary and backup stationary power applications (for industry, datacenters, commercial/residential buildings), and long-duration energy storage for the grid. Fuel cell technologies can also be used for combined heat and power generation or in innovative, hybrid approaches such as in tri-generation (power, heat, and hydrogen) applications.

The development of additional stationary applications will further promote fuel cell manufacturing demand, especially in end uses where fuel cells developed for medium- and heavy-duty applications can be readily applied. This topic seeks to explore innovative stationary power generation applications, that could support hydrogen infrastructure development, including but not limited to concepts that could address hydrogen fueling station challenges (e.g., hydrogen leakage and boil-off); hydrogen utilization for electric vehicle charging; and pipeline operations. Fuel cells can support pipeline operations, for instance by providing cathodic protection of pipelines from corrosion. Also, fuel cells can utilize hydrogen or even natural gas in the pipeline to provide power to support pipeline operation (e.g., at compressor stations).

The topic also seeks the design and development of subsystems that would complement and benefit from fuel cell byproducts (heat and water). As an example, the topic encourages the development of novel devices which could collect and use water product for remote locations and emergency situations; or provide heat to support infrastructure operations.

Phase I applications should provide preliminary analysis and designs that support a business case for the recommended novel application. The topic is technology neutral, but the utilization of fuel cells to support demand and the development of economies of scale, as well as strengthen the domestic supply chain are encouraged.

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Questions – Contact: Will Gibbons, William.Gibbons@ee.doe.gov

b. Novel Materials for Use in Liquid Hydrogen Service

This subtopic solicits applications to develop and demonstrate novel materials for two key use areas for cryogenic liquid hydrogen: novel materials for use as seals in components; and novel composite materials for use in vessels and components for liquid hydrogen storage. Hydrogen has a normal boiling point of 20 K (-253 °C) and a critical temperature of 33 K (-240 °C). These ultralow cryogenic temperatures are well below the glass transition temperature for most commonly used elastomeric materials used as seals in component applications such as valve seats. Also, composite materials used in pressure vessels may become very brittle and be susceptible to cracking at these cryogenic temperatures, thus reducing their effectiveness for use in applications that undergo numerous and/or large pressure cycles. It is anticipated that in applications, such as for medium- and heavy-duty transportation, liquid hydrogen will be extensively used to supply and store hydrogen to fueling stations and potentially to store hydrogen onboard vehicles. To reduce the cost and improve the performance of fueling stations able to meet targeted back-to-back fueling rates at an average of 10 kg H2/minute and onboard storage pressures of up to 700 bar, efforts are underway to develop high-speed cryogenic liquid pumps and compressors. Due to the higher density of liquid hydrogen compared to compressed hydrogen gas, there are also efforts to develop low-cost, lightweight tanks capable of storing liquid hydrogen onboard the vehicles, including aircraft. Some liquid hydrogen storage applications are considering operating pressures of up to approximately 20 bar, however other concepts are investigating supercritical pressurized hydrogen storage of up to several hundred bar at cryogenic temperatures. This topic therefore seeks development and demonstration of novel materials that are durable and low-cost for use in components in cryogenic hydrogen service. Of specific interest are materials that can be used as seals in dynamic (e.g., in pumps) and static (e.g., face seals) conditions, valve seats, and pressure regulators at temperatures at least as low as 20 K. Novel materials for use in storage vessels must be low-cost and durable enough to be able to withstand thermal and pressure cycling to meet the specific application needs.
Phase I applications must describe the targeted use of the novel material, the current development status of the proposed material or approach to develop the material, and innovations targeted to improve on state-of-the-art materials. Applications must also describe plans to be able to test the materials to assess their likelihood of meeting performance required for the targeted application.

Questions – Contact: Kevin Carey, kevin.carey@ee.doe.gov

c. Novel Concepts for Hydrogen Infrastructure and Storage

This subtopic solicits applications to develop and demonstrate novel concepts for key areas of hydrogen storage and infrastructure. Hydrogen has potential to enable decarbonization of many transportation, chemical, and industrial processes. To be competitive with incumbent technologies, the cost of implementing high-capacity use of hydrogen must be reduced while improving the performance and durability of hydrogen infrastructure. It is anticipated that hydrogen will be stored and transported as a high-pressure compressed gas, an ultralow temperature cryogenic liquid, and as a hydrogen carrier, such as ammonia, methylcyclohexane, or formic acid. Temperatures experienced within various hydrogen applications could be as low as -253°C (20 K) or as high as several hundred degrees Celsius. Pressures could range from near ambient to more than 1000 bar. Some components employed in hydrogen infrastructure, such as compressor components and valve bodies, require extensive machining to fabricate, or require expensive materials, such as high tensile strength carbon fiber, leading to high component costs. Hydrogen has a relatively low density compared to conventional liquid fuels, leading to it being stored at high pressures in cylindrical vessels or at ultralow cryogenic temperatures in double-walled, vacuum jacketed vessels, thus limiting design flexibility for incorporation into vehicle and end-use systems. This topic therefore seeks development and demonstration of novel concepts for manufacturing of infrastructure hardware components and novel hydrogen storage concepts. Novel manufacturing concepts could include 3D manufacturing of complex shaped components to eliminate extensive machining from solid metal blocks, or alternative materials that may eliminate manufacturing processes and/or improve end-of-life recycling, such as use of thermoplastic resins instead of thermoset resins. Also of interest are novel hydrogen storage concepts that can increase the design flexibility to package hydrogen storage vessels, such as conformable systems, and/or how hydrogen is loaded and unloaded from the storage system.

Phase I applications must compare the proposed concepts to current state-of-the-art technologies. Manufacturing concepts must consider the cost and rate of manufacturing and storage concepts must consider the cost and system-level storage density of the stored hydrogen. Performance of the produced component or system must be projected and be able to meet the minimum requirements for the targeted application.

Questions – Contact: Kevin Carey, kevin.carey@ee.doe.gov

d. Power Take-off Units for Medium-Duty Fuel Cell Electric Vehicles

This subtopic solicits applications for the design and development of a power take-off unit that can be integrated in medium-duty (MD) fuel cell electric vehicles (FCEVs) to export power for construction, utility servicing, and recreational use.

Key metrics:

- Cost in terms of price per unit and/or total cost of ownership
- Total system energy efficiency
- Manufacturability (MRL)
- Size, weight, and power (SWAP)
- Interface with FCEVs: compatible with FCEV electrical bus architecture (voltage, power, etc.), communicates with engine control units (ECUs) using existing automotive standards and protocols (CANBUS, etc.)
- Exportable power
- Thermal management

MD FCEVs are a rapidly emerging vehicle class needed to address net-zero emission goals.[6] [7] These vehicles are largely used commercially in many vocations such as bucket/utility, construction, snow removal, and package delivery trucks. Many of the vocations require power take-off (PTOs) units to run vehicle implements or auxiliary application such as power tools on job sites. Mechanically driven PTOs are a mature incumbent technology that drive many of these applications by taking power from the transmission and transferring it to vehicle implements or handheld tools usually in the form of shaft and hydraulic power. With the growth of electric driven powertrains, there is a need to couple tools and implements to the electric drivetrain. FCEVs are ideally suited for work vehicles because of the large amounts of energy stored onboard the vehicle that can be used for work at a job site over an extended period of time.

[6] U.S. National Clean Hydrogen Strategy and Roadmap U.S. National Clean Hydrogen Strategy and Roadmap (energy.gov)
[7] Pathways to Commercial Liftoff: Clean Hydrogen Pathways to Commercial Liftoff - Clean Hydrogen (energy.gov)

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This subtopic seeks innovative concepts for development of an electric power take-off unit. The effort should align with previous efforts in the DOE SuperTruck programs on MD FCEVs[8] [9]

Operational and design specifications for the prototype electric PTO should include:

- Approximately 5-10 kW of exportable power
- Compelling use cases such as: welder, plow shovel, bucket, etc.
- Exportable power can be AC, shaft, or hydraulic. Exportable DC power is not desired.
- Safe electrical and machinal design with consideration of ground requirements during use.
- Prototype design should consider SAE J3253, with nominal vehicle bus voltages of ~800 VDC.[10]
- Vehicle-to-grid architectures are not desired.
- Vehicle-to-building architectures (via transfer switch) are not desired.
- Operating performance that matches incumbent technologies.

Phase I: Perform and document a design study for a prototype power takeoff unit. Develop a Phase II plan to validate the findings of the design study.

Phase II: Build a prototype PTO for validation of results from the PHASE I design study. Validation activities for the PTO system should include verifying energy efficiency, total cost including CAPEX and OPEX, and modeled integration with a vehicle system.

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

e. High Temperature Membranes and Membrane-Electrode Assemblies for Fuel Cell Operation (BIL Funded)

Proton exchange membrane (PEM) fuel cells – fueled by clean hydrogen – are a leading candidate to power zero emission vehicles. Several major automakers are commercializing light-duty fuel cell vehicles, and there is a growing market for fuel cell propulsion systems for medium- and heavy-duty vehicles like long haul trucks. PEM fuel cells are also of interest for stationary electric power generation, including primary power, backup power, and combined heat and power.

Commercial PEM technology for fuel cells is typically based on perfluorosulfonic acid ionomers (PFSA). PFSA-based polymer membranes for fuel cells, having high proton conductivity, low gas permeability, and excellent mechanical and chemical stability, have enabled the thriving PEM fuel cell industry, but intrinsic properties of PFSA ionomers limit the range of possible fuel cell operating conditions.

PEM fuel cells based on conventional PFSA are generally constrained to operate at temperatures below 90 °C and relative humidity greater than 70%. These operating constraints, which balance fuel cell performance against long-term degradation, have large implications for the fuel cell design that can drive up costs due to higher platinum-group metal (PGM) utilization, humidification, heat rejection, fuel processing, and bipolar plate material and manufacturing requirements. Increasing the PEM operating temperature can not only

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[8] High Efficiency Fuel Cell Application for Medium Duty Truck
High Efficiency Fuel Cell Application for Medium Duty Truck Vocations (energy.gov)

[9] Freight Emissions Reduction via Medium Duty Battery Electric and Hydrogen Fuel Cell Trucks with Green Hydrogen Production via New Electrolyzer Design and Electrical Utility Grid Coupling
Pathways to Commercial Liftoff - Clean Hydrogen (energy.gov)

[10] Electric Power Take-Off Interface Requirements for Commercial Vehicles Pathways to Commercial Vehicles – SAE J2325 J3253 (WIP) Electric Power Take-Off Interface Requirements for Commercial Vehicles - SAE International

increase PEM fuel cell performance and lower balance of plant requirements, but it can also increase fuel flexibility, allowing for the use of a variety of feedstocks including biomass derived fuels. Therefore, high temperature PEM (HT PEM) materials for fuel cell membranes and membrane electrode assemblies that operate at higher temperature, lower RH, and are compatible with conventional PEM fuel cell manufacturing processes could lower overall fuel cell costs and accelerate the green hydrogen economy.

This topic solicits applications to develop novel HT PEM ionomers, membranes, that are integrated into membrane-electrode assemblies. The topic encourages MEAs suitable for heavy-duty applications. Novel HT PEMs developed through this subtopic should have properties and characteristics required for high temperature, low RH application in PEM fuel cells, including:

- Membrane proton conductivity greater than 0.05 S/cm in a temperature range between 120°C and 200°C and over a range of relative humidities
- MEA performance degradation less than 1%/1000 h, which is commensurate with 10,000 h fuel cell durability, under relevant operating conditions
- Good film forming properties enabling formation of thin (<25 µm) uniform membranes
- Low swelling and low solubility in liquid water
- Low creep under a range of stress, temperature, pressure, and humidity conditions
- Low permeability to gases including H_2, O_2, and N_2

Phase I should include measurement of chemical and physical properties to demonstrate feasibility of achieving the properties and characteristics included above, and an evaluation of the feasibility of high-volume manufacturing.

Questions – Contact: Eric White, Eric.White@ee.doe.gov

f. Advanced Proton Exchange Membrane (PEM) Electrolyzer Bipolar Plates (BIL Funded)

This subtopic solicits applications to develop platinum group metal (PGM)-free coatings for bipolar plates (BPPs) and/or develop BPPs that utilize materials which are less expensive than titanium, which is typically used today. BPPs are a significant cost of PEM electrolyzers, even at high manufacturing rates.[11] These coatings and BPPs must be stable for PEM electrolyzer operation and ultimately meet 80,000-hour lifetime expectations while withstanding challenging operating conditions, including low pH, oxidizing voltages, and elevated temperatures.

BPPs play an important role in proton exchange membrane (PEM) electrolyzer performance by serving product separation, water management, and electronic conductivity functions. Ti plates enable high conductivities but are susceptible to oxidation, corrosion, and hydrogen embrittlement. Corrosion can be mitigated through a corrosion-resistant coating, which often includes precious metals such as Pt. HFTO seeks to assist the electrolyzer community in lowering costs of BPPs without sacrificing performance or lifetime.[12]

Phase I applications should provide details of the coating, treatment, and/or technology concept; the approach to validating feasibility of the concept at a prototype scale; plans for testing the fabricated plates at 3 A/cm^2 and evaluating degradation for 1000 hours; and evidence of how the concept will reduce costs of BPPs for PEM electrolyzers. We expect that during Phase I, applicants will develop the proposed technology

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[11] https://www.energy.gov/sites/default/files/2022-08/h2-amp-report-2022.pdf
[12] https://www.energy.gov/eere/fuelcells/technical-targets-proton-exchange-membrane-electrolysis

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and demonstrate its capability to be integrated in a PEM electrolyzer with, preferably, testing in a PEM electrolysis cell for sufficient time to adequately assess performance and durability.

Questions – Contact: Anne Marie Esposito, annemarie.esposito@ee.doe.gov

g. Novel Water Electrolyzer Concepts (BIL Funded)

This subtopic solicits applications to develop novel water electrolyzer concepts outside of traditional proton exchange membrane, alkaline exchange membrane, liquid alkaline, and oxide-ion or proton conducting solid oxide electrolyzer systems. Applications may include but are not limited to electrolysis concepts capable of intermediate temperature operation (125-450°C) including development of materials and components; membrane-less electrolyzer cell designs; or capillary-fed electrolyzers. For the purpose of this topic, water electrolysis is defined as using electricity to split water into hydrogen and oxygen.

Phase I applications should provide details about the electrolyzer technology concept and how it is advantageous over existing electrolyzer technologies, including cost, operational capabilities, performance, durability, and/or optimization for particular end users or industries. Applicants are encouraged to include performance estimates on a specific energy consumption basis (kWh electric/kg H_2 and kWh thermal/kg H_2) as well as estimates of the levelized hydrogen cost ($/kg H_2). We expect that during Phase 1, applicants will develop and/or optimize materials, components, and/or cell design for their proposed electrolyzer technology and conduct lab scale testing of the development to confirm the ability to efficiently split water into hydrogen and oxygen. Applications that propose electrolyzer designs that would lead to mixed O_2 and H_2 production streams or are otherwise unsafe to operate are not of interest.

Questions – Contact: Elias Pomeroy, elias.pomeroy@ee.doe.gov

C58-17. SOLAR ENERGY TECHNOLOGIES

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

The goal of the U.S. Department of Energy (DOE) Solar Energy Technologies Office (SETO) [1] is to accelerate the development and deployment of solar technology to support an equitable transition to a decarbonized electricity system by 2035 and decarbonized energy sector by 2050. Achieving this goal will support the nationwide effort to meet the threat of climate change and ensure that all Americans benefit from the transition to a clean energy economy. In 2021, DOE released the Solar Futures Study [2], a report that explores the role of solar energy in achieving these goals. SETO supports solar energy research, development, demonstration and technical assistance in five areas—photovoltaics (PV), concentrating solar-thermal power (CSP), systems integration, manufacturing and competitiveness, and soft costs—to improve the affordability, reliability, and domestic benefit of solar technologies on the electric grid.

The amount of U.S. electricity that is generated by solar technology is increasing. In 2012, approximately 0.3% of U.S. electricity generation came from solar energy; in 2021 this fraction was 3.9% and in 2022 it increased to 4.7%. In California, solar accounts for more than 27% of all electricity generated, with 16 states in total generating more than 5% from solar energy. [3] At the same time, the cost of solar electricity is decreasing, driven by global economies of scale, technology innovation, and greater confidence in PV technology. The levelized cost of energy (LCOE) benchmarks and actual power purchase agreement (PPA) prices for utility-scale

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PV systems have decreased more than 80% since 2010. [4] These low costs have driven the deployment of over 110 gigawatts alternating current (GWac) of solar cumulative capacity in the United States as of the end of 2022. In 2022, PV represented approximately 46% of new U.S. electric generation capacity compared to 15% in 2012. [3] Additional 5.7 GWac of PV were installed in Q1 of 2023, representing the largest Q1 on record [5].

Historically, SETO has supported the commercialization of solar innovations through funding opportunities and other programs that relate to one another but have their own unique attributes [6]. SETO uses the SBIR/STTR program [7] to encourage U.S. small businesses to engage in high-risk, innovative research and technology development with the potential for future commercialization. Other programs include the American-Made Solar Prize [8], the Solar Manufacturing Incubator Funding Opportunity Announcement [9], and the Technology Commercialization Fund [10]. For more information, please review SETO's Manufacturing and Competitiveness webpage [6] to find the best program for the technology readiness of your proposed technology and to make sure that the application aligns with the program's goals and objectives and our open funding opportunities [11].

This topic is open to both SBIR and STTR applications. Applicants who meet the qualification criteria for both the SBIR and the STTR programs, as defined in the funding opportunity announcement, are eligible and encouraged to apply to both programs, if they would like to do so.

Application Guidelines

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

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

Applications must include a clear assessment of the state of the art and how the proposed technology would represent a significant improvement, along with a basic cost-model analysis showing a path to becoming cost-competitive with current state of the art and the potential to increase solar generation on the grid.
Phase I awards that are part of this topic will be made in the form of a grant; SETO anticipates that Phase II awards will be made in the form of a cooperative agreement. In a cooperative agreement, DOE maintains substantial involvement in the definition of the scope, goals, and objectives of the project.

Applicants are strongly encouraged to use the table below as an example to include a summary of objectives they expect to achieve by the end of the Phase I period of performance. A similar table will be required in a Phase II application. DOE may negotiate project milestones with entities selected for a Phase II award. The table contains examples of each objective type, to guide you as you prepare your application. Each application should include technical, business, and stakeholder engagement-related objectives with clear, quantifiable, measurable, verifiable, aggressive yet realistic success metrics, and clear definitions of how completion of an objective will be assessed. Completion of a task or activity is not an objective. The table should be organized chronologically.

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This topic seeks to assist independent, growing small businesses that will successfully bring a new technology to the market and identify a profitable, self-sustaining business opportunity based on their innovation. This subtopic is not intended for creating a product, organization, service, or other entity or item that requires continued government support.

PERFORMANCE METRICS AND SUCCESS VALUES IN THIS TABLE ARE ONLY EXAMPLES AND DO NOT NECESSARILY REPRESENT OFFICE GOALS OR SUCCESS METRICS FOR THIS TOPIC.						
#	**Month of completion**	**Performance Metric**	**Success Value**	**Assessment Tool / Method of Measuring Success Value**	**Verification Process**	**Metric Justification, Additional Notes**
1	2	Cell efficiency	> 25% efficiency	Average, standard deviation. At least 10 cells measured under standard conditions. Standard deviation < 1% (absolute efficiency).	Raw data and graphs included in the progress / final report submitted to DOE according to the FARC.	The success value was chosen based on initial cost modeling. Efficiency lower than 25% makes this material not competitive with current state of the art.
2	3	Circuit model curation	> 30 models, of which at least 20 are suitable for testing	Count. 30 realistic and anonymized candidate distribution circuit models identified, of which at least 20 are suitable for detailed testing.	Description of circuit models, load models, impedances, and connectivity characteristics included in the progress / final report submitted to DOE according to the FARC.	Load models, impedances, and connectivity characteristics must be included in the report to assess the feasibility of the proposed circuits.
3	4	Feedback	> 10 potential users	Count. A minimum of 10 potential users of the tool will undergo a demo of the software (in-person or webinar) and provide feedback. Users must provide specific feedback as to the minimum availability and response time they require for their specific use case.	Documentation of feedback and a justified plan to implement or reject recommendations from potential users included in the progress / final report submitted to DOE according to the FARC.	User feedback is a critical part of an iterative development cycle to ensure the solution is useful to potential off-takers.
4	4	Module lifetime	> 30 years	Accelerated testing conducted according to testing procedures listed in IEC 1234.	Raw data and graphs included in the progress / final report submitted to DOE according to the FARC.	IEC 1234 is the industry-used module degradation test.
5	5	Heliostat installed cost	≤ $50/m^2$	Average expected accuracy range is +20%/-15%.	Cost model with description of assumptions used for input parameters, methodology for the sensitivity analysis, supporting documents used to determine the bill of materials included in the progress / final report submitted to DOE according to the FARC.	Success metrics defined in the FOA.

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PERFORMANCE METRICS AND SUCCESS VALUES IN THIS TABLE ARE ONLY EXAMPLES AND DO NOT NECESSARILY REPRESENT OFFICE GOALS OR SUCCESS METRICS FOR THIS TOPIC.						
#	**Month of completion**	**Performance Metric**	**Success Value**	**Assessment Tool / Method of Measuring Success Value**	**Verification Process**	**Metric Justification, Additional Notes**
6	5	Letters of Support	5 letters	Count. A minimum of 5 letters of support from domestic manufacturers. Includes one module producer with capacity over 200MW annually.	Letters included in the progress / final report submitted to DOE according to the FARC.	Engaging with a large domestic module manufacturer is essential to show there are interested technology off-takers.
7	6	Simulation validation	Single feeder simulation	Power flows validated on a single realistic distribution feeder in simulation. Phasor tracking shows agreement with expected power flows at every circuit node to better than 5%.	Quantitative simulation results included in the progress / final report submitted to DOE according to the FARC.	5% agreement is required to assess the quality of the simulation tools.
8	8	Independent expert review of security architecture	Third-party review	Report by independent third-party cybersecurity expert reviewing the architecture and providing feedback on potential weaknesses.	Security review report included in the progress / final report submitted to DOE according to the FARC..	Implications of new platform architecture in the context of new cybersecurity concerns must be investigated and mitigated if necessary.
9	9	Module efficiency	> 25% efficiency	Average, standard deviation. At least 10 modules measured under standard conditions. Standard deviation < 1% (absolute efficiency).	Raw data, graphs, and report from testing facility included in the progress / final report submitted to DOE according to the FARC.	The success value was chosen based on initial cost modeling. Efficiency lower than 25% makes this technology not competitive with current state of the art.
10	9	Binding letters of intent	2 letters	Count. A minimum of 2 letters of intent from relevant stakeholders committing to fabricate and test a large-scale prototype of this technology.	Letters included in the progress / final report submitted to DOE according to the FARC.	Success of the award will be measured by successful technology transfer to private entities.
11	9	Contract	> 1	Count. At least one agreement with a non-team-member to share data and beta test the solution.	Agreement included in the progress / final report submitted to DOE according to the FARC.	Success of the award will be measured by successful technology transfer to private entities.

Applications are sought in the following subtopics:

a. Power Electronic Technologies for Solar Systems

This subtopic solicits proposals for the development of the next generation of power-electronic systems for the solar industry that demonstrate substantial advantages compared to the current state of the art. Such advantages include, among others, higher efficiencies, smaller size and lower weight, enhanced functionality in terms of supplying loads and dealing with load variability, performing grid-control actions, and providing

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grid-support services. In addition, increased durability and reliability of inverters resulting from improved design and manufacturing processes are key aspects to consider.

As solar electricity costs continue to decrease, the percentage of solar photovoltaic generation (both from distributed and utility-scale systems) in the U.S. increases. [1] This opens up new challenges [2] and opportunities for the development of novel technologies that can enable low-cost, dispatchable solar generation that can be integrated and operated flexibly to better match solar electricity with demand while also having the ability to provide operating support services to the electricity grid. [3] In addition, solar generation is often coupled with energy storage systems (ESS) and electric vehicle (EV) charging stations creating the need for centralized, multi-port power electronic devices that can combine and manage all such systems in a unified architecture.

At the same time, wide-bandgap materials hold great promise to outperform traditional silicon-based devices in power electronic applications and in particular silicon carbide (SiC) and gallium nitride (GaN) devices have reached a level of maturity that allows them to become the device of choice in many applications. [4] The growing market demand for SiC-based power electronics is driven by the rising adoption of SiC devices by original equipment manufacturers (OEMs) of electric and hybrid vehicles, which is leading to their de-risking and widespread adoption. This creates an opportunity for their use in power-electronics components for the solar industry in a cost-competitive way compared to incumbent technologies. [4] Furthermore, the United States is a pre-eminent supplier of high-quality SiC wafers and chips, which—when used with advanced inverter/converter topologies that facilitate automated pick-and-place manufacturing—make a compelling case for domestic manufacturing. In addition to SiC and GaN, ultra-wide-bandgap semiconductors based on gallium oxide (Ga_2O_3) have shown potential for even greater performance potentially resulting in even higher efficiencies and power densities both in terms of weight and volume. [5-6]

This subtopic solicits proposals in the following areas:

- Innovative designs, devices, and systems of power-electronic equipment based on wide- or ultra-wide-bandgap semiconductor materials, such as SiC, GaN or Ga_2O_3, which leverage the performance advantages of such materials and the potential for automated manufacturability. Systems of interest are solar inverters, DC/DC converters/optimizers, or solid-state transformers. Such systems may implement innovative modular converter topologies, high-frequency transformers, planar magnetics, or transformerless designs to create cost-competitive, high-performance alternatives to today's industry-standard silicon-based equipment.
- Power electronics for highly integrated systems that consist of distributed PV paired with ESS and/or electric vehicle charging (EVC) systems—including vehicle-to-grid (V2G) and vehicle-to-home (V2H) functionalities. By leveraging the inherent flexibility of ESS and EVC technology, the integrated systems can reduce the total capital and operational costs of these distributed energy resource assets. They also have the potential to provide grid services, including on-demand energy, capacity, reliability, and resiliency. Solutions that also integrate EVC should be capable of delivering power necessary for high-power direct-current fast charging.
- Advanced power electronic control algorithms and schemes that improve the performance of solar inverters or other converters and allow for solar systems to provide grid-support services, such as grid-forming inverters. [3]
- Improved design and manufacturing processes for solar inverters/converters that could minimize failures and their impacts resulting in more reliable and durable power electronics devices for solar systems.

Applications should address issues of control coordination, interoperability, communication, component obsolescence, and scalability as lack of holistic designs and standard interfaces can result in added integration costs and operational complexity. Technologies proposed should leverage attributes specific to solar PV generation technologies while addressing current integration gaps and challenges. Applications must demonstrate potential to increase the utilization of solar PV generation in the grid and include a basic cost-model analysis showing a path to be cost-competitive with current state of the art.

Applications must include a clear assessment of the potential for domestic manufacturing. Proposed technologies must balance any power conversion cost increases with clear and substantiated value propositions from improved efficiency, performance, or reliability.

Applications much demonstrate a clear and direct impact to the solar industry and have a solar application or product as an end goal.

Applications will be considered nonresponsive and declined without external merit review if they do not have a clear, direct, and immediate relevance and impact to the solar industry and revolve around earlier-stage research and development that would be beneficial to multiple-industries.

Applications will be considered nonresponsive and declined without external merit review if their emphasis is not power electronic technologies and products specifically designed for solar applications or if their focus is general manufacturing of power semiconductor devices.

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

b. Supercritical Carbon Dioxide Power Cycles for Concentrating Solar Power (CSP)

This subtopic seeks applications to advance the components, design, and commercial maturity of supercritical carbon dioxide (sCO2) power cycles for CSP systems. sCO2 cycles such as the recompression Brayton cycle (RCBC) are uniquely beneficial for CSP due to the potential for high thermal to electric conversion efficiency, ability to scale to sizes between 5 and 100 MWe and amenability with dry cooling. Thermal to electric conversion efficiencies greater than 50% can be achieved at temperatures above 700°C. CSP systems (and therefore associated power cycles) gain value by incorporating thermal energy storage (TES) and must be designed to be dispatchable.

Realizing these efficiency advantages, however, requires further component development including turbomachinery, heat exchangers, piping, dry coolers, etc. Subcomponents such as dry gas seals, bearings, and other seals are of interest. Innovations that optimize sCO2 power cycles for CSP use are appropriate. sCO2 systems may also serve as a heat pump; adding energy to CSP thermal energy storage reservoirs is of interest. In all cases, applicants should target either concepts that could immediately be incorporated with commercial nitrate salt based CSP operating a turbine at 550°C or future Gen3 CSP applications with turbine inlet temperatures of 700°C or greater. Concepts targeting commercial CSP applications should clearly identify near term technology transition opportunities.

Cost, reliability, and efficiency improvements beyond state-of-the-art are of interest. Efforts to advance the manufacturing and commercial maturity of technologies or the integrated cycle are encouraged. Applicants should quantify expected impacts of the proposed efforts in these areas. Applicants are also expected to include the design, feasibility, testing, and cost validation of new or improved components and subsystems during their application.

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Supporting systems for high temperature sCO2 systems and components may also be of interest. This might include, for example, control systems, modelling, cycle design, metrology, material research, etc. Applicants should fully describe the applicability of such supporting technologies, along with the benefits expected.

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

c. Concentrating Solar-Thermal Power Technologies for Gen3 CSP, Commercial CSP (Gen2 CSP), or Concentrated Solar-Industrial Process Industrial Heat (SIPH)

While PV has dominated the U.S. solar market, with over 90 GW deployed by the end of 2020, CSP technologies offer a unique value as a renewable energy resource that can readily deliver high-temperature heat and inherently incorporates storage for on-demand solar energy. There are nearly 100 CSP plants in commercial operation worldwide, representing almost 7 GW of capacity. Existing CSP plants have already demonstrated long durations of daily storage, up to 15 hours, which increases their value to the grid. With integrated TES, CSP plants can produce consistent amounts of electricity on demand, regardless of the time of day or amount of cloud cover. Continued development of this technology will improve the performance, reliability, and cost of future CSP plants, which have the potential to provide between 25 and 160 GW of U.S. capacity by 2050. [1]

Additionally, achieving a net-zero carbon economy by 2050 will require the adoption of clean energy technologies in sectors beyond electricity generation. Technologies are required that can eliminate the need to burn fossil fuels for heat-driven processes that produce electricity, essential commodities, refined products, and other goods. Even with increasing amounts of available renewable electricity, many industrial processes will be difficult to electrify because they require high temperatures or have other unique process characteristics.

For next-generation CSP plants, SETO has set a target to lower the cost of electricity from baseload plants, with greater than 12 hours of storage, to $0.05/kWh by 2030.[2] This represents, approximately, a 50% reduction of existing costs. Although this target is aggressive, there are multiple pathways to achieve it. [3] The primary technical strategy being pursued to achieve this goal is to raise the temperature of the heat that next-generation CSP plants deliver to the power cycle, thereby increasing plant efficiency. Specifically, ‘Generation 3’ Concentrating Solar Power Systems[4] (Gen3 CSP) targets the development of high-temperature components and develops integrated designs with thermal energy storage that can reach operating temperatures greater than 700° Celsius (1,290° Fahrenheit). In March of 2021, SETO announced the selection of a Gen3 CSP pathway based on solid particle heat transfer media, led by Sandia National Laboratories, to receive approximately $25 million to build a megawatt-scale integrated test facility to validate the performance of this system.

Improvements in GEN3 CSP technologies are needed in systems, components for particle and gas receivers including, but not limited to, receivers, heat exchangers, thermal energy storage (TES), particle elevators, and in measurement and metrology.

Applicants may also seek to improve the reliability and reduce the cost of existing commercial CSP systems. SETO, working close with NREL [5], has identified potential areas of improvement with respect to reliability of operating CSP plants. The areas of interest include high impact components that have not been reliable. Areas that increase the operability, decrease the O&M costs, or decrease plant installation costs of commercial CSP plants are also of interest.

Beyond CSP for electricity, SETO works to make SIPH a cost-effective alternative to conventional fuels. SETO pursues cost reductions and process integration improvements for a range of temperatures and industrial applications. Developing scalable, low-cost solutions for this variety of applications is a key challenge. Candidate applications for SIPH includes both low-temperature processes, such as enhanced oil recovery, food processing, and water desalination, and high-temperature processes, such as calcination to produce cement, thermochemical water splitting for producing solar fuels, and ammonia synthesis for producing fertilizer.

This subtopic seeks the development of CSP technologies, components, systems, and materials relevant to either low-cost electricity production or the decarbonization of industrial thermal processes.

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

d. Solar Hardware and Software Technologies: Affordability, Reliability, Performance, and Manufacturing

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

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

- Innovative software solutions that will increase the competitiveness of the U.S. solar industry. This may include but is not limited to decreasing solar deployment barriers, expanding to new solar markets, reducing non-hardware costs of installations such as permitting, system design, or interconnection, and/or enabling new business models.
- Technologies that reduce the manufacturing costs of solar energy system components or subcomponents to boost domestic energy manufacturing and increase U.S. manufacturing competitiveness;
- Technologies that can measure, validate, or increase outdoor PV system reliability;
- Technologies which improve operation and maintenance of PV systems. Can include self-contained smart PV systems with sensors which detect actual or imminent power loss, or mobile instrumentation for low-cost field diagnostics.
- Hardware components for photovoltaic-thermal (PVT) technologies, including solar modules, collectors, and control systems;
- Technologies the enable the development and operation of virtual power plants (VPPs), which are a connected aggregation of DER technologies operated in a coordinated way. Such solutions should have a clear focus on solar DERs and VPPs that incorporate solar systems.
- Technologies enhancing the ability of solar energy systems to contribute to grid reliability, resiliency, and security;
- Cyber security technologies improving the ability of solar assets or electronic devices associated with solar energy generation (such as inverters, direct current (DC)-DC optimizers or other converters, and smart meters) and systems to protect themselves from and quickly recover in response to cyber threats;
- Technologies or solutions that reduce the balance-of-system costs of a PV system;
- Technologies that build on other SETO programs and/or leverage results and infrastructure developed through these programs. In the past few years, SETO has funded several programs to support multi-stakeholder teams as they research and develop solutions to reduce significant barriers to solar energy adoption through innovative models, technologies, and real-world data sets. The areas of interest,

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analysis, taxonomies, and best practices developed from these programs can be leveraged as the impetus for small business innovation;

- Technologies that can improve the overall recyclability and refurbishment of PV modules and/or other hardware or balance-of-system components of a solar system. These could include, but are not limited to, methods for extending the life of existing panels, methods for effectively recycling decommissioned modules, as well as processes for proclamation of key materials (e.g. silver, tellurium, aluminum, etc.), which could ameliorate supply chain issues and further reduce the overall environmental impact of the photovoltaic industry.
- Technologies or solutions for solar for grazing lands (primary interest) and other agricultural PV (APV) uses, where solar systems are collocated with agricultural processes and activities;
- Technology components and systems for application-specific needs such as building-integrated photovoltaics (BIPV), vehicle-integrated photovoltaics (VIPV), floating photovoltaics (FPV), or other infrastructure-integrated photovoltaic systems.

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

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

- Focus exclusively on HVAC or water heating applications;
- Propose products or projects for satellite or other space applications;
- Proposed products or applications of indoor or wearable PV;
- Propose development of concentrated PV or solar spectrum splitting technologies;
- Propose development of technologies with very low possibility of being manufactured domestically at a competitive cost (e.g., PV modules based on copper zinc tin sulfide (CZTS) or amorphous silicon thin films; technologies assuming incorporation of functional materials, such as quantum dots or luminescent solar concentrators);
- Propose technologies to improve the shade tolerance of PV modules;
- Include on business plans or proofs of concept that do not contain documentation supporting their necessity or benefit. Competitive approaches in this application segment should be clearly defined in the application;
- Focus on undifferentiated products, incremental advances, or duplicative products;
- Involve technologies that do not have a clear, direct, and immediate relevance and impact to the solar industry and do not have an immediate solar application or product as their end goal;
- Involve technologies that do not have a clear, direct, and immediate relevance and impact to the solar industry and do not have an immediate solar application or product as their end goal;
- Propose projects lacking substantial impact from federal funds. This subtopic intends to support projects where federal funds will provide a clear and measurable impact (e.g., retiring risk sufficiently for follow-on investment or catalyzing development). Projects that have sufficient monies and resources to be executed regardless of federal funds are not of interest;
- Duplicative software solutions with many existing competitors in the market, including software to facilitate system design or system monitoring and any software solution to improve customer acquisition processes;
- Propose development of ideas or technologies that have already received federal support for the same technology at the same technology readiness level.

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

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C58-18. WATER POWER TECHNOLOGIES (FAST-TRACK ONLY)

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

Hydropower

a. Community-Centric Hydropower Technologies Development and Partnerships

Marine Energy

b. Development of Marine Energy Systems in Open-Water Conditions
c. Coastal Structure Integrated Wave Energy Converters

The U.S. Department of Energy's (DOE) Water Power Technologies Office[13] (WPTO) enables research, development, and testing of new technologies to advance marine energy as well as next-generation hydropower and pumped storage systems for a flexible, reliable grid. To reduce marine energy costs and fully leverage hydropower's contribution to the grid, WPTO invests in research and technology design; validates performance and reliability for new technologies; develops and enables access to necessary testing infrastructure; and disseminates objective information and data for technology developers and decision makers.

WPTO is seeking "fast-track" or combined Phase I and II SBIR and STTR applications related to both Hydropower and Marine Energy technologies in the three subtopics described in this section.
In addition to the technical considerations described in the subtopic descriptions, ALL applications in this topic must:

- Propose a 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;

[13] https://www.energy.gov/eere/water/water-power-technologies-office

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- 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.
- Post-Phase II plan that outlines future work plans to ensure funded approaches reach end-users, including how companies will grow and ensure their systems reach end users.

a. Community-Centric Hydropower Technologies Development and Partnerships (BIL Funded)

Trusted and community-driven research is fundamental to multiple stakeholders including rule makers, environmental regulators, hydropower and water resource managers, technology researchers and developers, and, most importantly, communities in which technologies are deployed and used. Community-driven research can be co-beneficial for both small businesses owners and the disadvantaged communities where hydropower projects and/or broader hydropower research is located. However, these communities have often been left out in the research, development, deployment (RD&D), and even decision-making process. The goal of this topic is to encourage small businesses to incorporate community needs and inputs to the extent possible into their hydropower industry-related R&D. Additionally, this area of interest encourages the participation of small businesses in relevant hydropower-related industries from disadvantaged communities [1], and/or with extensive, substantive partnerships with disadvantaged communities.

Areas of interest under this topic may include:

- The collection of new hydropower data that may be community-based or leverages community-science approaches where applicable;
- Community partnership development to inform technology development. An acceptable partnership may include but is not limited to the following examples:
  a. Technology business and community-based organization and/or non-government organization representing a specific disadvantaged community;
  b. Hydropower developer and a water and/or electric utility;
  c. Non-powered dam owner/operator and a watershed protection committee;
  d. Partnership with tribal governments, organizations, and/or other representatives;
- New technologies that face cultural, economic, and societal hurdles to responsible and accelerated deployment;
- Siting, process, or engagement tools aimed at evaluating or minimizing impacts and maximizing benefits on disadvantaged communities;
- Small businesses seeking to enhance and modernize the hydropower industry and workforce;
- Programs to develop robust pipelines and programs that attract and train the next generation of the hydropower-related workforce through apprenticeships, recruitment and/or retention, on-site training opportunities, or other workforce priorities identified by the applicants.

Application Requirements:
Phase I

- Demonstrate a hydropower-industry related need in which the proposed solution is strengthened through community engagement and/or partnerships;
- Demonstrate an innovative that is hydropower related and includes community partnering, while addressing one or more of the above areas of interest. The community engagement should be treated as a core component of the project, with a design component and a robust implementation and evaluation plan. This plan should detail the method and level of involvement from members of the community organization partner(s);

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- Provide evidence that the team has sufficient experience, expertise, and/or capability in working in, or with disadvantaged communities through discussion of previous projects and/or partnerships, including lessons learned, successful strategies, and outcomes
- Partner with an organization representing at least one disadvantaged community and/or non-federal government entity;
- Provide a letter of support/commitment from the partnering community organization(s) towards participation in the project;
- Include an initial analysis of the applications' value to the community partner.
- Collect end-user/community requirements and converting collected requirements to into the innovation
- Provide results of implementation and an evaluation plan including methods and evidence of involvement from members of disadvantaged communities;
- Provide explanation of end-user/community engagement and collaboration and how their requirements and were integrated into the proposed concept.
- Provide plan -- that includes end-user/community engagement -- on next stages of the concept development, which may include: testing, siting, deployment, environmental risk identification and mitigation, and scalability.
- Deploy the system design based on findings from Phase I and perform a pilot of the community-driven technological solution.

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

b. Development of Marine Energy Systems in Open-Water Conditions (WEC/TEC Testing) (BIL Funded)

The development of marine energy systems in open-water conditions involves harnessing the power of the ocean to generate power for the grid (MW scale) or for alterative end users with lower power requirements (kW scale). Marine energy technologies have evolved significantly over the last several years with design convergence within tidal energy system development, although there has been a lack of design convergence within wave energy system development. The paradox of in sea testing is fast learning versus costly deployments with each 'system' having different design requirements. Ultimately DOE and WPTO's goal is to enable the development of cost-effective, reliable and survivable systems.

The objectives for this subtopic are to fast track in sea deployments that:

- Further cost effective in sea testing for wave energy converter and/or tidal energy converter (WEC / TEC) prototypes
- Demonstrate performance to the following metrics: reliability and survivability, maintainability and accessibility
- Fast track utilization of pre-permitted sites as appropriate to progress to Phase II;
- Utilizing academic offshore sites and or support for deployments encouraged.
- Test to IEC 62600 suite of marine energy standards encouraged.

Areas of interest for this subtopic include but are not limited to:

WEC prototypes	TEC prototypes
1 year and or performance in extreme wave conditions	90 days or performance during extreme marine conditions.
Full system prototype demonstration	Full system prototype demonstration
WEC and TEC prototypes	

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- Application of Technology Qualification (TQ) using IEC 62600 –4 standard with a recognized certification body
- Integrated environmental monitoring / data collection for WEC/TEC system performance

Requirements for this subtopic:
Phase I and Phase II
In addition to the requirements for all Water Power Technologies subtopics described at the beginning of this topic, for these fast track Phase I and Phase II combination proposals, competitive applicants should demonstrate knowledge, experience, and/or capabilities in developing marine technologies. They also should have a coherent plan for the project over the duration of both awards where a clear path can be understood.

Applicants should include as many of the following points in their proposals where appropriate for their topic:

- A conceptual and or full design of the proposed system;
- Identification of the specific ranges of marine energy resources necessary for the operation of the systems and the expected power production.
- A description of survival strategies during extreme weather events.
- Identification and description of the proposed performance metrics which will be used to assess the system.
- A description of the intended deployment location(s) and the available energy in the chosen marine energy resource, including identification of any key environmental, social, and regulatory challenges.
- Have a clear go / no go decision framework for moving onto to Phase ll.
- Present a detailed plan for technology commercialization including identification and engagement of end-users, near-term and long-term market opportunities, future demonstration and deployment plans, manufacturing and supply chain requirements.

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

c. Coastal Structure Integrated Wave Energy Converters (CSI-WEC) (BIL Funded)

Wave energy converters (WECs) can be integrated with existing or new coastal protection structures such as breakwaters, seawalls, and harbors to generate clean power while avoiding the environmental and operational risks of offshore marine energy deployment and supporting coastal resilience. While the development of these technologies remains nascent in the U.S., there are several successful long-term deployments internationally. This topic enables technology developers to test and demonstrate existing technologies, as well as advance new systems and novel concepts. Partnership with coastal infrastructure owners, operators, and end-users such as harbor and port entities, government organizations, and remote communities is highly encouraged but not required.

The potential value propositions of marine energy devices integrated with coastal protection structures are to provide coastal defense and energy extraction, shared infrastructure costs and reduction of costly sub-systems for offshore deployment such as anchoring or marine vessel operations, limited environmental impacts and potentially quicker permitting timelines, providing clean power to local communities, marinas and ports (e.g., navigation lights, recharging electric boats), and supporting local energy resiliency and reliability[1]. Any proposal to this topic area should be able to highlight key techno-economic assumptions behind their technology.

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The goals of this CSI-WEC topic include:

- Support development of existing technologies with a focus on refining and improving critical sub-systems such as PTO components, infrastructure design and integration, connection to local grids, and micro-grids and energy storage solutions.
- Innovative methods for integrating CSI-WECs to both new and existing coastal infrastructure.
- Assist startups and entrepreneurs who have novel CSI-WEC concepts in further developing these into viable solutions.
- Develop pilot-scale solutions to demonstrate commercial potential and adoption of these technologies as part of future renewable energy portfolios.

Applications must involve research, development, and demonstration in one or more of the opportunity areas below:

- Improvements to Existing CSI WEC Technologies
- Adaptions of Existing WEC Technologies to CSI
- Development of Novel CSI WEC Concepts

Application Requirements

Phase I and Phase II

In addition to the requirements for all Water Power Technologies subtopics described at the beginning of this topic, for these fast track Phase I and Phase II combination proposals, competitive applicants should demonstrate knowledge, experience, and/or capabilities in developing marine technologies. They also should have a coherent plan for the project over the duration of both awards where a clear path can be understood.

Applicants should include as many of the following points in their proposals where appropriate for their topic:

- A conceptual and or full design of the proposed system; this includes any necessary changes to the existing infrastructure.
- Explain the value proposition of their design to coastal communities, coastal defense systems and or local resiliency.
- Identification of the specific types of coastal structure typologies and locations where this technology could be deployed.
- Identification of the specific ranges of wave energy resources necessary for the operation of the WEC and the expected power production.
- A description of survival strategies during extreme weather events and or waves and or long-term sea-level rise.
- A description of how the system deals with tidal variability.
- A description of the maintainability of the WEC, especially where design provides significant cost reductions.
- Plan for preliminary proof-of-concept testing or modeling of system components or alternative methods to advance the technology.
- Identification and description of the proposed performance metrics which will be used to assess the system in comparison to other WEC technologies.
- A description of the intended deployment location(s) and the available energy, and an identification of any key environmental, social, and regulatory challenges.
- Details of work to be performed in Phase I including resources required and intended performance targets.
- Description of Phase II work including the scale of the demonstration prototype, the intended test location or facility, and potential end-user partners.

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- Levelized Cost of Energy Analysis (LCOE) or alternative techno-economic analysis.
- Have a clear go / no go decision framework for moving onto to Phase ll.
- A description of the plan to build, test, and demonstrate a functioning prototype in a realistic environment.
- A description of how the team will iterate system design based on ongoing laboratory and in-water experiments.
- Present a detailed plan for technology commercialization including identification and engagement of end-users, near-term and long-term market opportunities, future demonstration and deployment plans, manufacturing and supply chain requirements.
- Testing targets or benchmarks, expected data that will be provided to evaluate the benchmarks, system engineering requirements for the designs, simulation and modeling of their prototypes, technology and deployment risks, lessons learned documents

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

[1] LiVecchi, A., A. Copping, D. Jenne, A. Gorton, R. Preus, G. Gill, R. Robichaud, R. Green, S. Geerlofs, S. Gore, D. Hume, W. McShane, C. Schmaus, H. Spence. 2019. Powering the Blue Economy; Exploring Opportunities for Marine Renewable Energy in Maritime Markets. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Washington, D.C

References: Subtopic a:

1. Office of Economic Impact and Diversity, Justice40 Initiative, Energy Justice Policy, https://www.energy.gov/diversity/justice40-initiative (October 19, 2023)

C58-19. WATER POWER TECHNOLOGIES

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

Crosscutting

a. Emerging Sensors, Sensing Networks, and Other Monitoring Technologies
b. Innovations in Data Analytics, Models, and Tools

Hydropower

c. Pumped Storage Hydropower Innovative Concepts
d. Micro-Hydropower Development

Marine Energy

e. Co-Development of Marine Energy Technologies
f. Development of Marine Energy Components and Subsystems

The U.S. Department of Energy's (DOE) Water Power Technologies Office[14] (WPTO) enables research, development, and testing of new technologies to advance marine energy as well as next-generation hydropower and pumped storage systems for a flexible, reliable grid. To reduce marine energy costs and fully leverage hydropower's contribution to the grid, WPTO invests in research and technology design; validates performance and reliability for new technologies; develops and enables access to necessary testing infrastructure; and disseminates objective information and data for technology developers and decision makers.

[14] https://www.energy.gov/eere/water/water-power-technologies-office

WPTO is seeking SBIR and STTR applications related to both Hydropower and Marine Energy technologies in the six subtopics described in this section.

In addition to the technical considerations described in the subtopic descriptions, ALL applications in this topic must:

- Propose a 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;
- 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.
- Post-Phase II plan that outlines future work plans to ensure funded approaches reach end-users, including how companies will grow and ensure their systems reach end users.

a. Emerging Sensors, Sensing Networks, and Other Monitoring Technologies

Background

Advancing marine renewable energy technologies and hydropower efficiency and resilience relies on various sensing and monitoring technologies, data collection methods, instrument design, and more, for a wide range of applications ranging from new components in a device to monitoring of environmental conditions. The specific goals of this cross-cutting hydropower and marine energy subtopic are to:

- Encourage private sector approaches to solving gaps and challenges in sensors, instruments, or monitoring systems designed to collect data that supports the development of marine renewable energy and/or the longevity, efficiency, or resilience of hydroelectric generation. This includes innovative and feasible technologies that provide measurements to support work in climate change, hydrology, wave condition monitoring, and marine research and technology,
- Support startups and other small businesses focused on new approaches to data collection that may include innovations in AUVs, sensor platforms, or remote sensing.
- Support monitoring technologies and instruments focusing on traditional knowledge gaps, interdisciplinary approaches, and data collection across spatial and temporal scales, especially where discovery or collection of this data drives downstream knowledge, products, and methods.

Areas of interest include but are not limited to the following applications:

Marine Energy Applications	Hydropower Applications
• Resource characterization • Site analysis and characterization • Internet of Things (IoT) and offshore applications. • Open water testing instrumentation. • Powering the Blue Economy[15] • Environmental impacts and permitting • Marine spatial planning	• Water quality, quantity, or demand monitoring • Watershed-scale sensor networks • Greenhouse gas detection • Environmental or species monitoring • Asset monitoring
Cross-cutting Applications	

[15] Powering the Blue Economy | Department of Energy

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• Remote sensing • Environmental monitoring

Application Requirements
Applications must involve research, development, and/or demonstration of their proposed sensor, sensor network, or other monitoring technology. All applications must also meet the requirements outlined in the topic description for all Water Power Technologies Office projects.

Applicants seeking to develop or enhance data analytics, models, or tools (including leveraging existing data) for marine renewable energy and hydropower technologies should see Subtopic b below.

Competitive applicants should demonstrate knowledge, experience, and capabilities in engineering sensors or adapting existing ones for innovative purposes.

Phase I proposals for this subtopic must provide in their application:

- A clear description of the innovation;
- An articulation of the value proposition beyond the state of the art;
- Use case(s) with applicability to hydropower and/or marine energy systems or industries;
- A description of the pervasiveness of applicability;
- Example(s) of potential end-users and their data, analysis, and decision-making needs;
- A detailed plan for the development or enhancements of the technology including details of work to be performed in Phase I and resources required;
- Identification and description of metrics which will be used to assess the improvements made by the innovation;
- Establish firm characteristics of the data collected along with the means of storing and/or transmitting this data;
- Outline the lifespan, temporal resolution, and spatial resolution of the solution;
- Relevance of this project to DOE's climate change goals including through advancing clean energy and decarbonization, specifically how this project will advance increased availability of renewable energy, decrease fossil fuel emissions, and/or its potential to meet specific DOE technical targets or other relevant performance targets;
- Research the commercial potential for development of through practical use cases of said solution;
- Initial description of Phase II work.

Phase II proposals should state how awardees will:

- Identify and develop detailed plans for possible testing and demonstration, including:
    - target end-users,
    - specific partners and capacity of partnerships, and
    - budget;
- Develop the sensor solution as outlined in Phase I;
- Describe and perform a wide range of tests to ensure accuracy and precision and address uncertainty;
- Finalize the design of the sensor along with any necessary system support;
- Perform a series of testing on the sensor solution over a range of operational conditions;
- Complete the research on the commercial potential of the solution;
- Develop a report with recommendations on data collection needs of the hydropower and/or marine energy industry and the extent to which the solution developed mitigates those needs. This report

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should also detail the commercial potential and a path forward to commercializing the innovation and identifying a process for future industry uptake.

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

b. Innovations in Data Analytics, Models, and Tools

Background

State-of-the-art data analytics, models, and tools are required to solve design challenges for marine energy and hydropower projects, make maintenance decisions, and develop new hydroelectric operating regimes for a changing grid and climate. In an age of "big data", overcoming broad challenges related to marine renewable energy and hydropower requires innovations in:

1. *data analytics* that use and apply new methods (e.g., artificial intelligence) to draw upon new insights,
2. *models* capable of representing complex processes (e.g., digital twins, hydroclimate models), forecasting future conditions (e.g., component fatigue, wave fields) and projecting long-term outcomes (e.g., climate change impacts) and,
3. *tools* that translate data and models for decision-making, resource management and other applications (e.g., marine spatial planning, flood risk assessment).

This subtopic seeks innovative approaches in water-related data that could open new areas of opportunity and bring greater efficiencies or capabilities to hydropower and/or marine energy applications. The goals of this cross-cutting hydropower and marine energy topic are to support and encourage startups and other small business to:

- Solve gaps and challenges in the synthesis of existing marine energy- or hydropower-related data through advancements in data analytics. In recent years, data availability has rapidly expanded across water and energy resources but finding, collating, and analyzing that data for specific hydropower and/or marine energy applications has remained challenging.
- Develop advanced models that meet the evolving needs of marine energy developers, hydropower owners and operators, or other relevant stakeholders seeking insights into marine energy technologies and hydropower management.
- Process data and models for decision-making, assimilation, or other innovative data science tools. This can include novel commercial or open-source software or platforms that benefit marine energy and hydropower industries by incorporating new or existing data types into decision-making (e.g., social or economic data), simplifying data or model interpretation (e.g., data visualization), or increasing information collation, access, and equity (e.g., in applications of hydroinformatics).

WPTO is interested in innovations that either apply to marine energy OR hydropower OR both. Proposals should clearly address challenges and opportunities in one or more of the following: data analytics, modeling, or tools.

Areas of interest include but are not limited to the following:

Marine Energy Applications	Hydropower Applications
• Resource characterization	• Water quality, quantity, or demand modeling • Environmental or species decision-making • Mitigation tools • Asset management

• Powering the Blue Economy[16] • Environmental impacts and permitting • Spatial planning for testing and deployment • Control systems / Control Co-Design	
Cross-cutting Applications	
• Artificial intelligence and machine learning • Decision support tools • Interdisciplinary research • Incorporating qualitative and quantitative approaches • Modeling • Forecasting	

Application Requirements
Applications must involve research, development, and/or demonstration of their innovative data analytics, models, and/or tools. All applications must also meet the requirements outlined in the topic description for all Water Power Technologies Office projects.

Applicants seeking to build physical sensors and monitoring systems or deploy instrumentation to collect new data for marine renewable energy and hydropower technologies should see subtopic a "Emerging Sensors, Sensing Networks, and Other Monitoring Technologies" above.

Competitive applicants should demonstrate knowledge, experience, and capabilities in analyzing data or developing models and tools.

Phase I proposals for this subtopic must provide in their application:

- A clear description of the innovation and why it is novel;
- An articulation of the value proposition beyond the state of the art;
- Use case(s) with applicability to hydropower and/or marine energy systems or industries;
- A description of the pervasiveness of applicability;
- Example(s) of potential end-users and their data, analysis, and decision-making needs;
- A detailed plan for the development or enhancements of the new or existing data analytic, model, or tool;
- Identification and description of metrics which will be used to assess the improvements made by the innovation;
- Details of work to be performed in Phase I including resources required and intended performance targets;
- Relevance of this project to DOE's climate change goals including through advancing clean energy and decarbonization, specifically how this project will advance increased availability of renewable energy, decrease fossil fuel emissions, and/or its potential to meet specific DOE technical targets or other relevant performance targets;
- Initial description of Phase II work.

Phase II proposals should state how awardees will:

- Identify and develop detailed plans for possible testing and demonstration, including:

[16] Powering the Blue Economy | Department of Energy

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  - target end-users,
  - specific partners and capacity of partnerships, and
  - budget
- Describe and perform a wide range of tests to ensure accuracy and precision and address uncertainty.
- Finalize the development of the analytics, model, and/or tool which may include the publishing of code, user information or guides, beta versions, websites, subscriptions, etc.
- Develop a report on hydropower and/or marine energy industry needs and the extent to which the developed innovation addresses those needs. This report should also detail the commercial potential and a path forward to commercializing the innovation and identifying a process for future industry uptake.

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

c. Pumped Storage Hydropower Innovative Concepts

Pumped storage hydropower (PSH) provides over 90% of utility-scale electricity storage in the US, and it is the primary source of long-duration energy storage currently available. Increasing penetrations of variable resources such as wind and solar have made this storage increasingly important [1], and modeling results show that the need for long-duration storage will continue to increase [2]. However, PSH expansion has slowed, with only one new facility, San Vicente in San Diego, coming online in the US in the last 20 years. Several factors contribute to diminishing PSH growth in the US, including market uncertainty, development costs and financing concerns, long payback times, permitting challenges, construction risks, competition from other storage technologies, and technical challenges related to energy storage valuation [3].

DOE's HydroWIRES Initiative is aimed at increasing the flexibility of existing hydropower and overcoming PSH deployment barriers to support power system decarbonization [4]. Unconventional PSH configurations like underground and modular systems could solve some of the PSH deployment challenges, but none have reached commercial viability in the US. The time, cost, and risk of PSH development in today's markets have resulted in limited PSH growth, despite rising demand for energy storage.

Conventional PSH configurations have two water reservoirs at different elevations where gravity drives water from the upper reservoir to the lower reservoir. As water moves to the lower reservoir, it passes through a turbine-generator (discharge). The same system uses a powered pump-motor to move water back into the upper reservoir (recharge) [5]. The system therefore stores energy by pumping water to the upper reservoir at times of low demand and uses the stored water to generate energy during high demand.

This topic seeks proposals for innovative technologies to accelerate the deployment of PSH through improved PSH components or alternative / unconventional PSH configurations that reduce PSH costs and/or improve the value of PSH systems. Innovative technologies will address one or more of the following characteristics of PSH:
1. Reduce initial capital costs and/or operation & maintenance (O&M) costs
2. Increase operational revenue and value to the grid
3. Increase development and deployment speed
4. Reduce negative environmental and community impacts

The reduction of costs or increase of revenue and value should be quantified in terms of relevant asset value measurements, such as levelized cost of storage, internal rate of return, or net present value. Reduced time to commissioning should be demonstrated with detailed timelines highlighting the difference relative to conventional technologies and/or by corresponding reduction in costs. Metrics for environmental and community impacts may vary based on type of impact, but the application should present why the metric is a strong representation of the impacts.

While applicants may address multiple innovations stated above, proposals will be judged on the technology's total impact and not the number of characteristics addressed. Proposals should seek to commercialize technologies that address one of more of the above improvements to PSH.

In addition to addressing conventional PSH configurations, proposed innovations may also address unconventional PSH configurations. In addition to gravitational potential energy between two reservoirs at various elevations as described above, a pressure gradient between the two pressurized reservoirs can also facilitate potential energy difference. For proposals regarding unconventional configurations, applicants must provide a description of how their technology is an improvement to existing energy storage technologies.

Examples of unconventional PSH configurations currently in development are elaborated in Argonne National Lab's "Review of Technology Innovations for Pumped Storage Hydropower" [6]. The International Forum on Pumped Storage Hydropower also published the report "Innovative Pumped Storage Hydropower Configurations and Uses" with a similar analysis [7]. A technoeconomic assessment from Oak Ridge National Lab examines modular PSH configurations that can achieve lower costs through standardized manufacturing and excavation [8].

WPTO is *not* interested in configurations that:
1. Do not use water to drive a turbine-generator for producing electricity.
2. Have unique constraints (e.g., siting) limiting the number of possible deployments to fewer than 5.

Competitive applicants should demonstrate knowledge, experience, and capabilities in developing hydropower and PSH technologies. Applications should show:
1. How the proposed concept is an improvement in performance and/or reduction in cost compared to the state-of-the-art for incumbent technologies; and
2. How the system would operate, using conceptual designs, drawings, or schematics of the proposed system with estimated physical dimensions.

The applicants should plan to accomplish the following during Phase I:
1. Develop a comprehensive analysis of the commercial potential of the proposed PSH technology innovation (component or configuration) due to improved PSH installation and/or operation;
2. Provide detailed metrics and technoeconomic assessment that quantifies the innovation's improvement relative to current state-of-the-art in terms of cost/kW, cost/kWh, and performance. Metrics should correspond to categories in the Energy Storage Grand Challenge Cost and Performance Database [9];
3. Define clear constraints on where and how the PSH innovation can be deployed, including specific locations and sites as examples;
4. Produce detailed schematics and/or simulations illustrating the innovation's features and operating states and;
5. Prepare for Phase II with a plan for testing the component or configuration under a range of representative conditions, including the following details:
   a. intended performance targets and the metrics for measuring them;
   b. budget for testing equipment, facilities, and other resources required; and
   c. potential end-use partners and how the technology will benefit them.

During Phase II, awardees will:

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1. Conduct laboratory and/or field tests designed during Phase I, and
2. Identify and develop detailed plans for possible demonstration in the future, including:
   a. target site,
   b. specific partners and capacity of partnerships,
   c. budget, and
   d. policy and community considerations regarding target site and partners.

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

d. Micro-Hydropower Development

Micro-hydropower (5kW - 1MW) refers to a distributed energy resource that provides local and reliable energy services without several of the development challenges for larger hydropower projects. This subtopic seeks innovative technologies or approaches that enable cost-effective and timely deployments of micro-hydropower projects, particularly those at canal, conduit, and non-powered dam sites. Selected applicants are expected to conduct research and development activities in Phase I that will lead to testing, demonstration and/or deployment of a micro-hydropower project in Phase II.

Micro-hydropower development is of particular interest to WPTO because potential micro-hydropower projects are numerous (with many of the over 90,000 dams having less than 1MW of hydropower potential), are often exempt from federal licensing processes, and can provide electricity and resilience services directly to local stakeholders. However, these projects still face cost, timeline, and replicability challenges that could be remedied by innovations and deployment experience. Technologies of interest within micro-hydropower development include but are not limited to:

- Additively manufactured powertrain components
- Innovative applications of advanced materials
- Inverter-based designs
- Modular water-to-wire design packages.

During Phase I, awardees are expected to conduct research and development activities in preparation for testing, demonstration and/or deployment activities in Phase II. Phase I activities include site assessment, feasibility analyses, technology testing and validation, stakeholder engagement, quantification of non-energy benefits, device optimization, and other related commercialization activities. Phase II activities include licensing studies and applications, final engineering design, construction, commissioning, and testing. Deployments are not expected to be operational by the end of the project term, but awardees must indicate how progress towards operation will be monitored and reported.

Application Requirements

Applications must involve either innovative micro-hydropower technologies or innovative development approaches using commercially available technologies. Applicant technologies should apply to sites with expected capacities of 5kW – 1MW but may also include applicability to projects of other sizes. All applications must also meet the requirements outlined in the topic description for all Water Power Technologies Office projects.

Phase I proposals for this subtopic must provide in their application:

- A clear description of the innovation;
- An articulation of the value proposition beyond the state of the art;
- A description of the expected hydropower project size applicability range (kilowatts).

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- A description of the pervasiveness of applicability across U.S. water systems, using available resource assessments[17][18] as applicable;
- One or more potential deployment sites with relevant site information;
- Identification and description of metrics which will be used to assess the improvements made by the innovation, such as levelized cost of energy;
- Details of work to be performed in Phase I including resources required and intended performance targets;
- Relevance of this project to DOE's climate change goals including through advancing clean energy and decarbonization, specifically how this project will advance increased availability of renewable energy, decrease fossil fuel emissions, and/or its potential to meet specific DOE technical targets or other relevant performance targets;
- Initial description of Phase II work.

Phase II proposals should state how awardees will:
- Develop, manage, and enact the detailed project development timeline;
- Obtain necessary licenses and permits;
- Finance the project and assess project economics, including generation revenues, incentives, operation and maintenance costs, and other benefits;
- Mitigate environmental and social concerns during and after construction;
- Validate performance of the technology at the project site;
- Monitor and report progress towards the commissioning of the project;
- Develop a case study summary report on the micro-hydropower development process with lessons learned and best practices.

Competitive applications will:
- Demonstrate knowledge, experience, and capabilities in developing, licensing, and constructing hydropower projects.
- Clearly describe the facilities where testing activities will occur (if applicable), including the relevant equipment and testing methods.
- Obtain relevant preliminary permits or exemptions (e.g., FERC small hydropower or conduit exemptions) for Phase II deployment sites.
- Provide letters of support for any necessary partnerships, such as those with the water infrastructure owners (e.g., irrigation districts, water utilities, municipalities, or industrial companies) where the Phase II deployment will occur.

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

e. Co-Development of Marine Energy Technologies

The Co-Development of Marine Energy Technologies (CMET) subtopic seeks proposals for the development and design of new marine energy prototypes specific to the needs of an identified end user in the blue economy. Applicants may be technology developers and/or end users.

CMET seeks to advance near-term marine energy opportunities in the blue economy by supporting the development of solutions tightly coupled to end-user needs, as part of WPTO's Powering the Blue Economy Inititiative. Specifically, this subtopic seeks to support the development of industry projects that link marine

[17] https://hydrosource.ornl.gov/tool/npd_tools
[18] https://www.ornl.gov/project/assessing-us-conduit-hydropower-potential

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energy technologies together with blue economy energy end users to co-develop solutions specific to energy constraints.

A common underlying input for many of the activities in the blue economy is energy: fuel for ships, batteries for underwater vehicles, or high-pressure seawater for desalination systems. While some activities have access to cheap and reliable sources of energy, others do not. Energy inaccessibility limits operations and adds unnecessary costs. Removing or reducing these energy constraints through energy innovation could open new pathways for sustainable economic development. These applications of marine energy are not limited to electricity generation and can include marine energy for propulsion or pumping.

Blue economy markets and coastal communities present multiple opportunities and applications for marine energy technology developers; upfront engagement with blue economy end-users and coastal communities is essential to successful technology integration. The CMET topic is market agnostic but requires applicants to make a case for their proposed application through an initial analysis of the market's value and broader impact in their proposal. Should the project be awarded, a more refined market analysis will be required as part of the final report.

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

Application Requirements
In addition to the requirements for all Water Power Technologies subtopics described at the beginning of this topic, for Phase I proposals, competitive applicants should demonstrate knowledge, experience, and/or capabilities in developing marine technologies and include the following in their proposals:

- A preliminary design of the proposed system with estimated physical dimensions;
- A clear description on how the system would function;
- Identification of the marine energy resource that would be utilized;
- The end-user or customers that will be engaged during the project;
- Plan to incorporate customer needs based on interviews, workshops, expert panels, literature searches, and other methods;
- The method(s) by which customer needs will be converted into design requirements or specifications;
- The process by which design requirements will be converted to preliminary prototype designs;
- Table of design specifications for the system and how each relates to a customer need.
- Plan for preliminary proof-of-concept testing or modeling of system components;
- Identification and description of the proposed performance metrics which will be used to assess the system in comparison to incumbent technologies, such as levelized cost of energy, levelized avoided cost of energy, or other similar metrics – please refer to "Existing Ocean Energy Performance Metrics" for examples;
- A description of the intended deployment location(s) and the available energy in the chosen marine energy resource, including identification of any key environmental, social, and regulatory challenges;

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- The state-of-the-art for incumbent technologies and how the proposed design is an improvement in performance or reduction in cost;
- How the solution can be applied to other applications or end-uses;
- Relevance of this project to DOE's climate change goals including through advancing clean energy and decarbonization, specifically how this project will advance increased availability of renewable energy, decrease fossil fuel emissions, and/or its potential to meet specific DOE technical targets or other relevant performance targets;
- Description of how this project will enable climate and energy justice;
- Details of work to be performed in Phase I including resources required and intended performance targets; and
- Initial description of Phase II work including the scale of the demonstration prototype, the intended test location or facility, and potential end-user partners.

Phase II proposals should state how awardees will:
- Refine system designs based on the findings from Phase I towards building a functional prototype;
- Build, test, and demonstrate a functioning prototype in a realistic environment;
- Iterate system design based on ongoing laboratory and in-water experiments;
- Present a detailed plan for technology commercialization including identification and engagement of end-users, near-term and long-term market opportunities, future demonstration and deployment plans, manufacturing and supply chain requirements;

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

f. Development of Marine Energy Components / Subsystems

The development of marine energy components faces several reliability challenges due to the harsh and dynamic marine environment which they will ultimately perform in. The technical complexities for manufacturing and subsystem integration with costly economic factors are significant challenges to address. The goal for this subtopic is to mitigate these challenges through improved design development efforts that focus on the identification, understanding and testing of all environmental conditions that components will withstand once fully integrated at the subsystem or system level and deployed in sea. The testing efforts on a test rig, tank or within facilities that provide testing environments mimicking the harsh environments are vital to addressing component reliability.

The objectives for this subtopic are:
- Single component characterization and model validation – to support WEC/TEC developer efforts where coupling of two dynamic systems is challenging and testing at subsystem level may not be achievable due to lack of bench testing infrastructure.
- Advancing Manufacturing for ME components and subsystems
- Development of other ME enabling technologies cables, sensors
- Require / encourage ME developer partnerships

Areas of interest for this subtopic but not limited to:

Components
Seals Electrical generators, power electronics and or grid connection equipment/components Connectors wet mate or dry mate

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Fiber optics for comms and or data collection Hinges; Pulleys, Crankshafts, levers, Actuators, Springs, Belts, Chains, Bearings
Cross Cutting Subsystems
Integrated environmental monitoring / data collection sensors for WEC/TEC system performance SCADA/DAQ's subsystems for comms

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

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WIND ENERGY TECHNOLOGIES OVERVIEW

EERE's Wind Energy Technologies Office (WETO) [1] invests in wind energy research, development, demonstration, and deployment activities that enable and accelerate the innovations needed to advance offshore, land-based, and distributed wind systems; reduce the cost of wind energy; drive deployment in an environmentally conscious manner; and facilitate the integration of high levels of wind energy with the electric grid. This work aims to drive down the cost of wind energy through competitively selected, cost-shared projects, carried out in collaboration with industry, universities, research institutions, and other stakeholders.

President Biden has set ambitious clean energy goals to put America on an irreversible path to achieve a 100% clean energy economy with net-zero emission no later than 2050 [2]. Wind energy—both offshore and land-based—has an especially important role to play in decarbonizing the grid and achieving a robust U.S. clean energy economy. As of August 2023, more than 144 GW of wind energy was installed across the United States [3], with the potential for 5 to 10 times that amount to be installed by 2035 to meet domestic decarbonization goals [4].

Reaching wind energy deployment goals will bring multiple benefits to the United States, including:
- New economic benefits from enabling large-scale clean energy deployment
- Tens of thousands of good-paying, middle-class, union jobs and a skilled workforce
- More U.S. manufacturing and supply chain opportunities.

Ongoing technology advances will allow us to produce wind turbines more cost effectively and capture more wind for all applications: offshore, land-based and distributed wind. To spur the aggressive deployment needed to achieve the Biden Administration's goals progress on these fronts, arising from continued innovation in technology, grid systems integration, and unique solutions to deployment challenges, can position the U.S. as a global leader in wind energy development at home and abroad.

Across all its wind energy development objectives, WETO emphasizes three common and overarching themes:
- Reduce the cost of wind energy for all wind applications (offshore, land-based utility-scale, and distributed).
- Accelerate the deployment of wind energy through siting and environmental solutions to reduce environmental impacts, minimizing timetables for wind energy project development, and facilitating responsible, sustainable, and equitable development and delivery of wind energy resources.
- Enable and facilitate the interconnection and integration of substantial amounts of wind energy into the dynamic and rapidly evolving energy system that is cost-effective, cybersecure, reliable, and resilient, and includes systems integrated with other energy technologies and energy storage.

All applications must:

- Include technical, business, and stakeholder engagement-related objectives with clear, quantifiable, measurable, verifiable, aggressive, yet realistic, success metrics, and clear definitions of how completion of an objective will be assessed, supported by literature-based articulation of the baseline and quantitative success metrics, where feasible.

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- Include projections for price and/or performance improvements that are tied to a baseline (i.e., 100% Clean Electricity by 2035 Study [5], wind technology market reports [6] and/or state-of-the-art products or practices).
- Explicitly and thoroughly differentiate the proposed innovation with respect to existing commercially available products or solutions expressing how the technical advancements will advance the state of the art.
- Include a preliminary cost analysis and justify all performance claims with theoretical predictions and/or relevant experimental data.
- Include a strong justification of the need for such technical advancements from the perspective of wind research and development, or energy siting and permitting.

Where applicable, applications should demonstrate interest from wind energy original equipment manufacturers and/or owner/operators regarding potential use of the technologies or where the end user is a regulatory body. The nature of that interest in and/or support of that body regarding the products of the research project should also be identified.

C58-20. OFFSHORE WIND ENVIRONMENTAL MONITORING TECHNOLOGY DEVELOPMENT

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
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

Properly sited and operated offshore wind turbines lead to increased environmental and economic benefits for communities that host renewable energy development, and to the nation overall. WETO works to understand and mitigate challenges to offshore wind energy deployment and operation. This includes engaging with stakeholders, facilitating research, and disseminating results on cost-effective approaches to monitoring and minimizing the environmental impacts of offshore wind energy. Offshore wind energy development and operations can negatively affect wildlife, which can delay U.S. offshore wind development and potentially impact wildlife populations. Reducing these impacts through objective, scientifically sound siting and minimization strategies helps ensure the benefits outweigh the challenges. To support environmentally sustainable development of offshore wind energy in the United States, WETO invests in innovative, cost-effective technologies that can refine our understanding of these risks and minimize wildlife impacts at offshore wind farms [7].

a. Offshore Wind Energy Technology Solutions to Advance Monitoring for Wildlife Risk

Offshore wind energy has the potential to provide a significant source of clean and renewable energy. However, the construction and operation of offshore wind farms can pose risks to wildlife, particularly birds and marine mammals. To mitigate these risks and advance monitoring for wildlife risk, various technology solutions and strategies can be employed.

Our focus in this subtopic is to enhance technology for better monitoring and tracking of wildlife in the vicinity of offshore wind energy facilities. This is crucial for gaining insights into wildlife behavior and minimizing potential risks, particularly in the challenging offshore environment. One specific challenge is understanding how birds and bats interact with wind turbines year-round, especially when there's no stable platform for observation.

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Although data from Europe suggests that bird collisions with wind turbines are likely infrequent [8], it is important to confirm this in the context of U.S. waters. Additionally, there is a growing interest in improving our ability to predict and detect the presence of whales near commercial-scale offshore wind energy projects. While some tools are currently available for this purpose, enhancing and expanding these tools would enable developers to extend their construction schedules, potentially including overnight pile driving, while also reducing the potential impact on marine life.

This subtopic solicits innovative R&D applications for the following areas of interest:

- Technology that helps us better observe and understand birds and bats in the offshore environment, using tools like avian radar and infrared camera to track them in three dimensions.
- Technology that can detect whale presence in real time in and around offshore wind construction areas (e.g., real-time passive acoustic monitoring, infra-red cameras, aerial surveys, and drones).
- Improvements to wildlife tracking and tagging technologies (e.g., global positioning system tags)
- Supporting oceanographic data collection techniques to improve our ability to predict and detect whale presence based on understanding where their food source is and how sound travels underwater.

Questions – Contact: Joy Page, joy.page@ee.doe.gov

b. Other

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

Questions – Contact: Joy Page, joy.page@ee.doe.gov

C58-21. JOINT WIND ENERGY TECHNOLOGIES OFFICE/OFFICE OF ELECTRICITY TOPIC: ENERGY STORAGE FOR 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
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

WETO works with electric grid operators, utilities, regulators, academia, and industry to create new strategies for incorporating increasing amounts of wind energy into the power system while maintaining economic and reliable operation of the grid. Energy storage for wind refers to the practice of storing excess electricity generated by wind turbines for later use. Wind energy generation is variable because it depends on the strength and consistency of the wind. Sometimes, wind turbines produce more electricity than is needed in real-time, while at other times, they may not generate enough to meet demand. Energy storage systems are used to address this variability and uncertainty and ensure a stable and reliable energy supply. Overall, energy storage for wind is a key component of a reliable and sustainable energy system that can harness the abundant energy resource of wind while addressing its inherent intermittency [9].

a. Compact Long Duration Storage for Wind

The U.S. electric grid is undergoing a transformation to a carbon free future by 2035. Currently at 10%, it is estimated that by 2035, wind will produce more than 30% of total U.S. electricity [10]. The deployment of energy storage is expected to grow exponentially during the transition to help balance the system with dominating weather-based resources like wind and solar.

While storage can be a standalone grid asset, supporting intermittent source of power generation is becoming critical to maintaining reliability. As such, renewable energy and storage hybrid project are gaining more and more traction. In 2022, more than half of the battery storage capacity waiting for transmission was paired with some form of generation, primarily solar [11]. The number for wind and energy storage applications is comparatively ignorable.

One of the factors driving this need is the unpredictable and variable nature of wind energy, which contrasts with the more predictable daily pattern of solar energy. This distinctive feature of wind power demands the development of a creative, compact, and long-duration energy storage technology, along with efficient controls. These innovations are necessary to transform wind energy into a highly controllable and dependable source of electricity. This comprehensive wind storage system can be applied not only at the large-scale transmission level but also at the smaller distribution level. This helps enhance the resilience of local and regional power systems while reducing the expenses and risks associated with expanding the grid.

Expanding on this idea is the DOE's Long Duration Storage Shot program [12]. Its main aim is to slash the cost of long-duration energy storage for the power grid by a whopping 90% in the next ten years. This initiative is open to exploring all sorts of technologies, whether they rely on chemistry, mechanics, heat, or various materials, either individually or combined, as long as they have the potential to meet the required duration and cost goals to make the power grid more flexible.

This subtopic solicits innovative R&D applications for the following specific areas of interest:

- Proof of concept design for an innovative long duration storage technology that can be either co-located with individual wind turbines, or installed at the wind plant collector station, for either/or both onshore and offshore wind applications. Desired features include but not limited to:
  - > 10 hours of duration
  - > 20 years of lifespan
  - Scalable cost to meet Long Duration Storage Shot cost targets
  - Compact for co-located design with individual turbines and for offshore wind applications.
  - Lightweight (preferably non-lithium) for offshore wind applications
  - Optional DC couple systems: DC-DC integration of LDES and Wind for power quality control and applications (including overgeneration controls)
  - Round Trip Efficiency (RTE) > 70%
- Proof of concept control development to maximize the value of wind storage systems
- At least one use-case analysis to evaluate the benefit and cost of the fully integrated wind storage system
- If possible, capture, maintain and share storage performance data (consider data share/integration with ROVI initiative [13]
- Evaluate benefits of pairing the “Storage as a Transmission Asset (SATA).”

Questions – Contact: Mohamed Kamaludeen mohamed.kamaludeen@hq.doe.gov and Jian Fu, jian.fu@ee.doe.gov

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C58-22. VEHICLE TECHNOLOGIES OFFICE

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
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

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) focuses on reducing the cost and improving the performance of vehicle technologies that can reduce petroleum dependency, 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

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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. Innovative Electric Vehicle Battery Cells and Components

Applications are sought to develop electrochemical energy storage technologies that support commercialization of electric vehicles, including innovative battery cells and battery components. The primary focus of this topic is to improve the state of the art for battery cells for ultimate adoption in future EVs. Energy density, cost, and safety are the key metrics to be addressed at the materials or cell level. The table below outlines the specific development areas that are of interest and are not of interest to this topic.

Areas of Development	Topic of Interest	Not of Interest
Cathode	• Sulfur-based • Co-free • Cathodes for sodium-ion batteries (Ni-free) • Li polyanion-based CAMs	• CAM Specific Energies <500 Wh/kg • Cost >$15/g (at scale) • Prussian blue/white cathodes for NIB • Ni content >60% • NCM/A processing/development
Anode	• Li-metal (foil or bare current collector with lithiated cathode) • Production and scaling of thin Li metal • Si-containing (>15%) • Anodes for sodium-ion batteries (alloy, hard carbon, intercalation)	• Graphite • Low specific capacity (<350 mAh/g)

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Electrolyte	• Solid-state • Low-cost • Enables long calendar life for Si anodes (>10 years)	• Multivalent ion (Mg, Ca, Zn, Al, etc) • Dual ion • Low conductivity (<1 mS/cm for solid, <5 mS/cm for liquid) • Dual electrolyte
Safety	• Cell- or component level safety improvements (electrolyte, separator, cell casing)	• Pack/Module level safety
Manufacturing	• Dry electrode processing • Electrode active material improvements (reduced cost, energy consumption, time, waste)	• Manufacturing of commercially relevant materials (e.g. NMC, LFP, graphite)
Cell Design	• Design for recycling (all components) • Lower cost through reduced inactive material	• Tab/case laser welding
Misc.	• High energy density: • >160 Wh/kg for sodium-ion or for low-cost Co/Ni-free lithium-ion • >300 Wh/kg for Ni-containing lithium-ion • Low-cost <$65/kWh (cell level) • Use of AI for materials discovery	• Recycling of cathode material • Pack, Module, or BMS level work • Fast charge work • Digital Twins

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 on the USABC website [1]. The work must focus on battery material and cell-level innovations; pack-level work is not of interest, including demonstrations of battery pack integration in vehicles. Phase I feasibility studies must be evaluated in full cells (not half-cells); at minimum, a single-layer pouch cell. Phase II technologies should be demonstrated in full cells ≥1 Ah capacity. The final technical report should include a comparison of the demonstrated cell level performance with the state of the art for that size and technology.

All submissions should clearly explain how the proposed work differs from other work in the field and should not be duplicative of ongoing projects. The DOE Vehicle Technologies Office Battery program goals and project performance can be referenced from our Annual Progress Report [2].

Questions – Contact: Dr. Nico Eidson, Nicolas.Eidson@ee.doe.gov

b. High Voltage (≥3.3 kV, ≥ 200 A) Half-Bridge SiC Power Module for High Voltage Electric Vehicle Charging Systems and Solid-State Transformers (SSTs)

Currently, new EV charging installation sites with DCFCs in locations that require grid upgrades suffer significant delays in the load service connection process due to constraints in the supply chain for distribution level low frequency transformers (LFTs). Innovative power electronics solutions, specifically high frequency

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solid-state transformers (SSTs), have shown promise to replace conventional LFTs to step down the grid voltage from medium voltage (MV ~13.8 kVAC) to a low voltage (LV = 480VAC) input for DCFCs while also providing modularity/scalability, as well as the isolation critical for protecting the electrical grid. These solutions utilize medium voltage level isolated power electronics with high frequency transformers to provide the isolation, as well as to step-down the bus voltage to the voltage range necessary for EV charging. SSTs have a high-power semiconductor component count due to the higher working voltage levels and total power levels (≥ 1MW). The increase in power component count per phase adds complexity to control of the system and increases risks due to the availability of commercial off the shelf (COTS) power semiconductor modules for both the active front end (AFE) and the dual-active bridge (DAB). Typically, a combination of 1.2 kV and 1.7 kV silicon carbide (SiC) power modules are utilized for state-of-the-art (SOA) MV grid-tied SSTs. The total power density, component count, and system control complexity of SSTs for EV DCFC installations can be significantly improved by utilizing ≥3.3 kV SiC power modules.

Currently, ≥3.3 kV SiC power modules are produced by U.S. companies. (e.g., Wolfspeed) and foreign companies (e.g., Hitachi, Mitsubishi), however due to the limited production and high cost, these components are seldomly used in non-proprietary applications. This topic seeks to develop/establish a U.S. domestic manufacturing capability with a cost structure that will allow for commercialization of a competitively priced product for global marketing based on innovative packaging solutions (in the form of ≥ 150 A power modules) supporting ≥3.3 kV capability of SiC MOSFETs commercially available in the U.S. This topic intends to also find innovative, low-cost, efficient, and power dense solutions to improve availability of WBG HV power modules for utilization in high power EV charging and grid-tied SSTs. Power density likeness to COTS XHP3, nHPD2, and LinPAK –class power modules is encouraged. Proposals should show a path towards domestic manufacturing of a high voltage packaging solution that takes a holistic, multi-physics design approach; optimizing for trade-offs between minimizing electrical packaging parasitics (capacitance and inductance) that are the natural result of necessary clearance and creep-age spacing needed for high voltage operation.

The following specifications are suggested:

- Configuration: Half-Bridge
- Voltage Rating: 3.3 kV – 10 kV
- Current Rating: ≥ 200 A
- Insulation Requirements (based on IEC 61800-5-1):
  - Required impulse withstand voltage: 8,692 V for overvoltage category 2
    - Assuming nominal system supply voltage of 2,400 V DC / 1,700 V AC rms
  - Required minimum clearance distance for functional and basic insulation: 9.1 mm for pollution degree 3
    - Assuming impulse voltage of 8,692 V and application altitude ≤ 2 km
  - Required minimum creep-age distance for functional and basic insulation: 21.3 mm for pollution degree 3
    - Assuming system rms voltage of 1,700 Vrms, application altitude ≤ 2 km, and insulating CTI material group 1
- Packaging parasitics (impedance calculated at 100 kHz)
  - Stray inductance in the power loop: ≤ 50 nH
  - Stray capacitance between substrate and case: ≤ 100 pF
- Operating Temperature: ≥ 175 °C
- Junction-to-Case Thermal Resistance: ≤ 0.07 °C /W

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Applications must clearly demonstrate 1) how the proposed work will improve on or meet the current SOA performance and 2) cost-effective pathways for commercial adoption in DCFCs and/or grid protection power electronics systems.

In Phase 1, projects should aim to design and simulate/model a ≥3.3 kV 200 A SiC power module, including electrical and thermal characteristics. Projects should also aim to provide pathways for commercialization and scalability. Phase I should include in-depth analysis of the electrical and thermal properties of the proposed innovation to demonstrate technology viability, with plans to prototype and test one unit in Phase II.

Questions— Contact: Fernando Salcedo, Electrification R&D, Vehicle Technologies Office, fernando.salcedo@ee.doe.gov

c. Energy Efficient Mobility Systems (EEMS): Increasing Efficiency Through Systemwide Innovation

This area of interest is led by the Vehicle Technologies Office (VTO) which funds early-stage, high-risk research that develops new, affordable, efficient, and clean transportation options that increase domestic economic opportunities. EEMS is one of the major programs within VTO and conducts early-stage research and development (R&D) at the vehicle, traveler, and system levels, creating knowledge, insights, tools, and technology solutions that increase mobility energy productivity for individuals and businesses. This multi-level approach is critical to understanding the opportunities that exist for optimizing the overall transportation system. The EEMS Program uses this approach to develop tools and capabilities to evaluate the energy impacts of new mobility solutions, and to create new technologies that provide economic benefits to all Americans through enhanced mobility.

An overview of the EEMS program is best provided through the VTO Annual Merit Review database [1] and through Annual Progress Reports [2]. For this SBIR area of interest, the EEMS program welcomes applications that focus on developing *innovative* solutions that improve transportation efficiency (people and/or goods) through methods such as greater coordination, communication, control, reliability, increased utilization of efficient resources, analytics, and other systemwide applications. Examples of technologies of interest include, but are not limited to:

- Technologies that improve transit optimization
- Technologies to enable First-mile/last-mile connectivity
- Micro-transit
- Technologies that increase transit utilization
- Spontaneous CACC/platooning, in practice
- Technologies that enable electrification/alt fuels, in practice
- Retrofitting

Successful applications should: clearly address the inefficiency/problem they are addressing; clearly show how their solution will improve efficiency and how this improvement will be measured (described in terms of carbon, energy, or fuel); and show a path towards delivering their solution or generating revenue. Applications that use or seek to further develop automated technologies to enable shared mobility are encouraged; however, automated technology solutions are not required for this area of interest. Applications that are not of interest are straightforward implementations of existing technologies and solutions; this sub-topic seeks innovative ideas. Applications that are primarily focused on procurement will be considered non-responsive.

EEMS recognizes that smartphone applications ("apps") may be a part of any shared mobility solution. However, applications whose primary effort appears to be in app development will be considered non-responsive.

Applications deemed to be duplicative of research that is already in progress by VTO, as well as by other agencies, including state and local governments, and by the private sector, will not be funded; therefore, all submissions should clearly explain how the proposed work differs from other work in the field. Note that the area of improving shared mobility is an area of active research and where many jurisdictions have many "pilot" programs. The intent of this SBIR subtopic is to complement these efforts.

Questions – Contact: Dr. Avi Mersky, Vehicle Technologies Office, Avi.Mersky@ee.doe.gov and Energy Efficient Mobility Systems (EEMS) eems@ee.doe.gov

d. Multifunctional and Intelligent Composites for Vehicle Applications

As automotive vehicles evolve, the need for more integrated and advanced sensing capabilities grows, particularly with the advent of autonomous and connected vehicles. With the unique advantage of embedding sensors, multifunctional and intelligent composite materials are expected to play an increasingly integral role in the evolution of vehicles, enabling them to be not only lighter and more energy-efficient, but also smarter, safer, and more comfortable to ride. Incorporating sensing functionalities directly into the structural and non-structural materials of a vehicle can lead to more responsive systems, better predictive maintenance, enhanced safety features, and a more seamless integration of technology into the vehicle design. As multifunctional and intelligent composite materials continue to advance, their role in automotive evolution is expected to expand significantly.

Vehicle lightweighting provides opportunities to increase driving range, reduce battery size and cost, and carbon emissions. Novel lightweight multifunctional and intelligent composite materials have the capability to reduce weight and volume as well as costs of conventional structural components by performing engineering functions beyond load carrying capacity. The multifunctionality that couples between structural performance and additional functionalities (e.g., electrical, magnetic, optical, thermal, chemical, and biological, etc.) is critical to the growth of artificial intelligence in the automotive industry. Cyber-physical systems that integrate various materials with sensing, computation, control and networking into physical objects and infrastructure, connecting them to the Internet and to each other, will be a common platform for most of the future infrastructures and mobile systems. Driverless cars powered by emission-free energy systems will be able to communicate securely with each other on smart roads to coordinate and reduce delays while monitoring the health and safety condition of the vehicles themselves anytime and anywhere. Multifunctional and intelligent composites can sense, diagnose, and respond for adjustment with minimum external intervention; allow alternation of shape functionality and mechanical properties on demand; and structurally integrate power harvesting, energy storage, and transmission capabilities for self-sustaining systems.[1] Such multifunctional and intelligent composite materials are required to make a step change in vehicle energy efficiency and reduction of the carbon footprint, particularly for electric vehicles (EVs) and autonomous vehicles (AVs)[2].

Furthermore, according to the 2015 U.S. DOT Report, Beyond Traffic[3], the U.S. population is expected to grow from 320 million in 2015 to 390 million in 2045. This growth will further congest our existing transportation system at an annual waste of over 40 hours/traveler. Millennials (aged 18 to 34) are driving less due to concerns about climate change. These national/societal issues in transportation mobility require a revolution from the existing aging transportation systems to a future affordable, intelligent, sustainable, and resilient

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high-speed mass transit system for cultural and social connections between the projected 11 U.S. megaregions and their surrounding cities.

This subtopic seeks proposals to develop, design, and demonstrate the feasibility of the proposed innovations that can incorporate the autonomic structures; adaptive structures; and/or self-sustaining systems in the next generation of high-performance and high-efficient vehicles. Innovative vehicle solutions to improve transportation equity, environmental sustainability, and renewable energy utilization are to be sought. The resultant multifunctional and intelligent composite system must align with VTO Materials Technology Program goals of the total composites costing less than $5/kg-saved weight on their subsequent lives. Novel matrices and/or reinforcements that significantly reduce the embodied energy of vehicle components by more than 50% and carbon footprint of composites manufacturing by more than 75%, and lower manufacturing cost by more than 50% compared to the conventional composites are encouraged. Various types of vehicles that would benefit from lightweighting and autonomy will be of the interest including agricultural vehicles, industrial vehicles, aerial electric vehicles, and transit, etc. Should it be successful, such multifunctional and intelligent composite systems could transform the current EV/AV platform.

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

e. Biodiesel Fraction In-Situ Measurement Devices or Methods for Off-Road Vehicles

The use of biodiesel blends has become prevalent among off-road vehicles with the expectation of reaching 100% biodiesel in some applications. However, due to colder climates, availability, blending with conventional diesel, etc., the in-situ concentration of biodiesel for a particular vehicle is generally unknown. Engine manufacturers may desire to adjust operation for optimal combustion/emissions depending on the biodiesel content (especially as source blends go beyond 20% biofuel) and without active measurement are forced to compromise performance. Off-road vehicles are likely to be particularly adversely affected by this compromise due to their seasonal use, frequent bulk purchases, and longer lifetimes.

Phase I work will concentrate on demonstration of the technology chosen to detect biodiesel fraction of conventional diesel fuels (#1 and #2) between 20 and 100%. Reporting accuracy must be at least +/- 5% when tested on known stocks.

Phase II work will focus on industrialization and commercialization of the sensors. During Phase II, a small batch of production-intent sensors (at least 10) will be tested on vehicle to demonstrate the feasibility of operation in representative conditions for at least 500 hours of total operation with varying Biodiesel blends between B20 and B100. The accuracy of reporting shall not fall below that which was required in Phase I

All submissions must meet following criteria:

- Proposals must focus on off-road vehicle applications, but it is recognized that such technologies are likely to be sufficiently generic to be adopted to on-road applications.
- Proposals should be for direct measurements, networks, or fusions of sensors. Proposals may include models and virtual sensors. Proposals need not introduce new sensors to the vehicle if they can utilize existing sensors in new ways to achieve the stated goal.
- Solutions should be low-cost (<$50/piece, projected to high-volume)
- Solutions must meet industry standards for vehicle lifetimes and operating environments.

Non-volatile components in fuel tanks (water, algae, fuel treatments, dyes, etc.) should neither alter nor reduce the accuracy of the proposed solution.

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Questions—Contact: Nick Hansford, Nicholas.hansford@ee.doe.gov

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PROGRAM AREA OVERVIEW – OFFICE OF FOSSIL ENERGY AND CARBON MANAGEMENT

The mission of the Office of Fossil Energy and Carbon Management (FECM) is to minimize the environmental impacts of fossil fuels while working towards net-zero emissions. The Office's programs use research, development, demonstration, and deployment approaches to advance technologies to reduce carbon emissions and other environmental impacts of fossil fuel production and use, particularly the hardest-to-decarbonize applications in the electricity and industrial sectors. Priority areas of technology work include point-source carbon capture, hydrogen with carbon management, methane emissions reduction, critical mineral production, and carbon dioxide removal to address the accumulated CO_2 emissions in the atmosphere.

To meet these challenges, FECM focuses on technology priority areas of point-source carbon capture, carbon transport and storage, carbon dioxide conversion, hydrogen with carbon management, methane emissions reduction, critical minerals (CM) production, and CO_2 removal. FECM recognizes that global decarbonization is essential to meeting climate goals—100% carbon pollution free electricity by 2035 and net-zero greenhouse gas (GHG) emissions economy-wide by 2050—and works to engage with international colleagues to leverage expertise in these areas. FECM is also committed to improving the conditions of communities impacted by the legacy of fossil fuel use and to supporting a healthy economic transition that accelerates the growth of good-paying jobs.

For additional information regarding the Office of Fossil Energy and Carbon Management priorities, visit Office of Fossil Energy and Carbon Management | Department of Energy

C58-23. CARBON CAPTURE, CONVERSION, AND STORAGE

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

To achieve net-zero carbon emissions economy-wide by 2050, technology development must address issues in the secure and cost-effective capture, conversion, transport, storage, and utilization of carbon dioxide. This topic brings together development needs identified in five programs in FECM's Office of Carbon Management Technologies: Carbon Transport and Storage, CO_2 Conversion, Integrated Carbon Management, and Point Source Carbon Capture. Subtopics include onsite carbon dioxide conversion to synthetic aggregates, carbon capture for mobile sources, and AI-based forecasting models for emissions.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Applications are sought for the following subtopics:

a. Synthetic Aggregates Production via Carbon Conversion (BIL Funded)

Mineralization is a carbon conversion pathway that can convert CO_2 into inorganic products such as synthetic aggregates, carbonated cements, supplementary cementitious materials, and soil amendments. As a carbon conversion pathway, mineralization tends to be scalable, require few energy inputs, use commercial off the shelf processing equipment, and have the capability to co-process waste streams. Ideally, mineralization products (as compared to incumbent products) offer superior technical performance, enable lower emissions, and cost less.

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Grant applications are sought for the research and development of carbon conversion technologies to produce synthetic aggregates that demonstrate life cycle analysis (LCA) greenhouse gas emissions that are at least 10% (and preferably 25%) lower than equivalent incumbent products on a cradle to gate basis. Grant applications must identify a specific end use for the synthetic aggregate. These end uses include but are not limited to; concrete, chip seal, insulation, drainage, void fills (clean fill), and mortar. In consideration of the specific end use, the grant application should enumerate performance specifications for the synthetic aggregate (e.g. density, hardness, size/shape, water absorption, cost, etc.) The Phase I work plan should include all testing necessary to determine whether the synthetic aggregate meets these performance specifications.

Grant applications should identify a power or industrial CO_2 source that would be converted in a commercial effort, and the Phase I work plan should specify a synthetic gas steam that is representative of the proposed CO_2 source (e.g., temperature, pressure, composition, impurities/contaminants). Acceptable CO_2 sources are point sources such as power plants, industrial emissions, and concentrated CO_2 from capture technologies (including direct air capture). If the mineralization process requires additional alkalinity, the source, quantity, and availability of the alkalinity source must be detailed. Alkalinity sources of interest include but are not limited to; industrial wastes (e.g., cement kiln dust, steel slag, fly ash, spray dryer absorber ash, circulating dry scrubber ash, and aluminum processing wastes), biomass residuals, industrial brines, and natural brines including those produced from oil and natural gas wells. The Phase I work plan should also include preliminary life cycle analysis (LCA) and techno-economic analysis (TEA) to understand how the process emissions and economics of synthetic aggregates compares to the incumbent product, respectively. Proposed technologies should, to the greatest extent practicable, utilize commercial off the shelf processing technology to minimize technological risk and development time.

Grant applications shall focus on:

- Research and development of carbon conversion technologies to produce synthetic aggregates which demonstrate life cycle greenhouse gas emissions that are at least 10% (and preferably 25%) lower than an equivalent incumbent product on a cradle to gate basis
- Identifying a specific end use for the product, enumerating performance specifications, and describing a Phase I work plan quantify performance
- Outlining a preliminary life cycle analysis (LCA) to be completed during Phase I
- Outlining a preliminary techno-economic analysis (TEA) to be completed during Phase I
- Utilizing commercial off the shelf processing technology, to the extent practicable

Questions – Contact: Michael Stanton, Michael.Stanton@netl.doe.gov

b. Carbon Capture for Mobile Sources

The transport sector currently accounts for 24 % of CO_2 emissions[1], and thus has been an important focus of global decarbonization efforts. Although battery electric and hydrogen fuel cell vehicles are promising alternatives for emissions mitigation, heavy-duty overland transportation and long-range marine transportation remain hard to decarbonize. Thus, the Point Source Capture Program is supporting the development of technologies for reducing the carbon intensity of mobile sources. These approaches involve onboard CO_2 capture and storage processes that can be integrated into an exhaust gas post-treatment system, reducing CO_2 emissions into the atmosphere. CO_2 capture from mobile sources presents unique technical challenges relative to stationary point sources including space and weight requirements, on-board CO_2 storage and variable exhaust conditions and operating profiles associated with acceleration and deceleration. The exhaust conditions of various mobile sources are summarized in Table 1.[2] It is therefore necessary to assess the feasibility of existing technologies and develop new technologies that can operate under these constraints for implementation in mobile systems.

Table 1: Representative exhaust conditions for various mobile point sources (Adapted from Voice et al[2]).

Application	Exhaust Temperature (°C)	CO_2 (%v)	Exhaust rate (kg/min)
Car	450	12	1
Truck	310	9	15
Ship	220	4.5	700

Applications are sought for mobile carbon capture approaches for on-road, off-road and long-range marine transportation. These approaches should encompass CO_2 capture, onboard CO_2 storage and/or onboard conversion, and CO_2 offtake if applicable. Significant progress towards achieving decarbonized transport should be demonstrated. Hybrid approaches such as electrification and use of low carbon fuels coupled with mobile carbon capture to enable full decarbonization are encouraged. Projects will conduct a *conceptual design and feasibility study of a mobile carbon capture process*. This design will include: (a) process flow diagrams and description of the component technology including operating conditions, (b) heat and mass balances of the process including specifications of energy sources for CO_2 regeneration and offtake, (c) proposed scheme for CO_2 offtake from the mobile source including CO_2 purity and pressure requirements, (d) specifications of size and weight of the capture and onboard storage unit and (e) evaluation of the CO_2 capture rate and of the ability of the capture system to perform in transient operating conditions (i.e.. acceleration and deceleration). Additionally, this effort will involve (f) a technology gap analysis for identification of critical elements that need to be further developed and validated, (g) a detailed life cycle analysis (LCA) and (h) a technoeconomic analysis (TEA). These analyses will include a comparison of the proposed approach with other decarbonization options e.g. electrification (battery electric vehicles) and hydrogen fuel cell. Selected projects may also conduct limited lab-scale experimentation to support proof of concept. of the mobile carbon capture technology conceptualized.

Applicants shall focus their applications on:

- Describing the capture system design with material and energy flows in sufficient detail to allow for an evaluation of the proposed concept. Descriptions should also include:
    - Approach used for CO_2 capture (sorbents, solvents or others)
    - Approach to CO_2 regeneration, including regeneration method, energy source and consumption (including possibility to utilize waste heat) and regeneration frequency
    - Approach used for on-board CO_2 storage and/or conversion (if applicable)
    - Approach used for CO_2 offtake including requirements for CO_2 pressure and purity (if applicable)
    - Preliminary calculations of size and weight of the capture system and on-board CO_2 storage
- Outlining a preliminary life cycle analysis (LCA)
- Outlining a preliminary techno-economic analysis (TEA). The LCA and TEA should demonstrate competitiveness of the proposed technology in comparison with existing decarbonization alternatives (e.g. electrification and hydrogen fuel cells).
- Limited lab-scale experimentation on the mobile carbon capture process to support initial feasibility of the concept

Questions – Contact: Dylan Leary, dylan.leary@netl.doe.gov

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c. AI Based Forecasting Models for Amine and Degradation Product Emissions

Wide-scale deployment of transformational carbon capture technologies installed at industrial or electric power generation facilities requires adequate control of emissions associated with the host site and with the carbon capture technology. Solvent-based carbon capture can improve air quality by removing pollutants such as sulfur dioxides from host facilities, but there is potential for solvents to degrade resulting in different products that need to be carefully managed and avoided using solvent management practices and engineering controls.[1,2] Amine-based solvents, which are promising candidates for post-combustion capture, can undergo thermal and oxidative degradation resulting in the formation of a variety of products.[3] Formation of degradation products may be particularly challenging for operation under non-steady state conditions including plant start-up and shutdown, where emissions profiles may vary significantly. Thus, solvent management is important in order to understand and effectively mitigate these emissions in a wide range of operating conditions.

Applications are sought for the development and implementation of machine learning (ML) tools that can forecast emissions. Test data from a recent campaign at Technology Center Mongstad (TCM) using CESAR1 solvent for post-combustion capture from residue fluid catalytic cracker (RFCC) flue gas[4] can be used for model development. Emissions data for this campaign consisting of Fourier-transform infrared spectroscopy (FT-IR) emission traces collected at the lean flue gas outlet will be provided. A sample of these data including details on operating parameters, flows and compositions is included in Reference 5 (along with a process flow diagram) in order to provide applicants with an understanding of the type of information available to serve as the basis for the model. Successful applicants who elect to use the available TCM data will be required to establish a data use/model sharing agreement with TCM and to acquire more test campaign data under different conditions. Applicants looking to develop a model based on a different set of test campaign data are also encouraged.

Capabilities of the model should include: (a) *Real time prediction of future emissions* products given historic test campaign data provided, including operating parameters; (b) *Causal impact analysis of the data*: provide a baseline of emissions that would have occurred without changes in operating conditions; (c) *Emissions mitigation:* use the models to predict emissions in "what if" scenarios (i.e. if the campaign was run with different operating conditions) to provide recommendations on plant operation. This topic area supports Infrastructure Investment and Jobs Act (IIJA) Title III: Fuels and Technology Infrastructure Investments; Subtitle A: Carbon Capture, Utilization, Storage and Infrastructure.

Applicants should focus their applications on:

- Description of the ML model proposed and anticipated capabilities
- Details of anticipated computational time and process complexity
- Ability of the ML model to be applied to different sets of test campaign data with different carbon capture technologies
- Ability of the ML model to ultimately be integrated with online measurements and engineering process control approach

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

d. Carbon Transport and Injection: Asset Integrity Management/Design

This subtopic seeks to develop new software programs for CO_2 service transportation and/or storage systems that can assess the system's hardware design under various operating and fluid conditions and determine asset integrity constraints to advance safe and robust selection and design of hardware.

Applications are being sought:
To address the DoE's need for accelerating commercial liftoff in carbon management, new digital tools and technologies are desired to assess, evaluate, predict, and potentially monitor the asset integrity of carbon transportation system hardware and individual components (e.g., booster equipment, pipelines, casing and tubing, etc.) when exposed to carbon dioxide with various impurities and operating conditions throughout an asset's design life. This project encompassing research specific to address relatively shorter duration asset integrity threats such as chemical compatibility (i.e., strong acid drop out), material compatibility, weld failure, and/or potential material failure (e.g., overload, collapse, etc.). The result of the project will be a software program that can be applied either as a plug-in or stand-alone software tool that supports proper material selection and design development for CO_2 specific transportation or storage systems and leverages various existing codes, standards, and published peer-reviewed research.

Questions – Contact: Liz Wilson, liz.wilson@netl.doe.gov

e. Turn-Key Service to Create a Gravity-Based Geophysical Monitoring Network for Use During Carbon Storage Operations

The carbon storage program has focused on developing processes and tools that can accurately and affordably assess the CO_2 plume location after commercial storage operations have started. In the site characterization phase of a storage project, there is a strong need to identify base-line subsurface conditions and to identify geologic anomalies. The idea is to establish a basis for comparison of geophysical measurements made before CO_2 injection with those measurements made at various points in time after CO_2 injection begins. With the optimally placed measurements of multiple relevant geophysical parameters, the goal is to map the location of the plume of injected CO_2 within the storage reservoir and identify significant CO_2 fluid flows into shallower permeable strata where smaller CO_2 plumes form. Recently, DOE's SBIR program solicited turn-key passive seismic monitoring networks and services, electrical and electromagnetic monitoring services, and high-resolution reservoir fluid pressure monitoring services.

Here a new SBIR subtopic solicits for deep subsurface interrogation and geophysical monitoring networks deploying gravity-based methods, whereby a balance is sought between a fit-for-purpose number and placement of gravity field sensors along with the sensitivity, data collection frequency (if applicable), and types of sensors for accurate detection of the very small changes in mass associated with CO_2 plume growth. CO_2 plume growth within thick permeable strata is detectable by gravity-based measurements (see, e.g., Jacob et al. 2016; Eiken 2018; Appriou et al. 2020; Gasperikova and Li 2021). These networks would include an intelligent level of data processing and streamlined preliminary interpretation that does not create a burdensome task for carbon storage project developers and operators. Because geophysical monitoring remains an important factor across the project lifecycle (prior to, during, and after CO_2 injection), an additional consideration should be placed on the robust and rugged nature of the system design and field ready gravimeters or sensors to support deployment over months to more than 30 years, with an outlook that the system could be expanded, updated or upgraded for further use as the subsurface CO_2 plume grows and in later phases of the project.

Joint inversion of time-lapse multi-physics data sets (e.g., active seismic data, passive seismic data, electrical resistivity data, electromagnetic field data, strain data, stress and pressure data, and gravimetric measurements) is widely believed to be a superior method for mapping and quantifying CO_2 plumes in sedimentary rock strata. CO_2 that leaks through the main seals and into a shallower permeable stratum will expand due to the reduced fluid pressures making the density of the CO_2 less and the leakage plume more

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detectable. Because injected CO_2 may initially push native brines upwards through seal layers into overlying permeable rock layers, the higher-density brines intruding into low-salinity brines could be detectable, even mappable in some cases. While joint inversion is not within the scope of this subtopic area, the monitoring network should be designed to allow for data acquisition supporting joint inversion of the gravity data along with other geophysical data sets.

Grant applications are sought for turn-key systems and services that facilitate easier, better, higher-resolution data acquisition and interpretation of CO_2 plume location(s). Other geophysical monitoring (e.g., active seismic, passive seismic, electrical resistivity (ER), magnetotelluric (MT), self potential (SP), and electromagnetic monitoring networks) are not within the scope of this funding opportunity, other than considering opportunities to instrument ground-surface monitoring stations and boreholes with more than one type of geophysical monitoring system. Ideally, gravity monitoring should be done during the site characterization phase (to get baseline data), commercial operations phase, and/or post-injection site care phase, for a broad range of site conditions, either onshore or offshore.

To enable this step increase, the goal is to develop a turn-key service that will deliver to the customer a site-specific monitoring system design, followed by installation of the complete monitoring system, coupled with a tailored level of processing and right-sized data storage and archiving (which is readily accessible by the storage-site developer or operator). Applicants should consider the cost effectiveness of combining more than one geophysics method, and the potential for joint inversion of gravity data with seismic and electromagnetic data (although seismic and electromagnetic methods are not directly within the scope of this subtopic area, nor are the methods of gravity data interpretation or joint inversions).

Gravimeters or other types of sensors sensitive to differences in mass/density at depth can be placed at the land surface or on the sea floor, in shallow boreholes or, on a limited basis, in deep boreholes, and may be deployed in conjunction with other geophysical sensors (e.g., seismic or electromagnetic). Gravimeters or sensors may also be towed through the air, across the land surface, or through/upon water bodies. Methods that are minimally disruptive to surface owners and current land use are preferred. Data interpretation may depend on a priori geologic models, borehole data, interpreted seismic data or other constraints; however, the inverse problem must be solvable for a volume of rock large enough to be of value in addressing the concerns identified above for a commercial-scale, geologic CO_2 storage complex. The focus of this funding opportunity is not the development of hardware or software; however, hardware and software development can be a small part of the project (a future solicitation may fund such developments further). Nor is this funding opportunity for the development of “imaging” software; however, this can be a small part of the project. Separately, under the SMART Initiative, DOE is developing methods and software for converting (and jointly inverting) raw to semi-processed data streams (including gravity data) in near real time into visualizations of subsurface conditions.

Phase I Projects that progress into Phase II under the SBIR grant program will be expected to field test their gravity-based monitoring system, preferably in a full system demonstration at a site injecting supercritical CO_2, or at an analog site.

Questions – Contact: Liz Wilson, liz.wilson@netl.doe.gov

f. Other

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

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Questions – Contact: Liz Wilson, liz.wilson@netl.doe.gov

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C58-24. CARBON DIOXIDE REMOVAL

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
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

Direct air capture (DAC) involves the extraction of carbon dioxide (CO_2) directly from ambient air in either motive (fan-powered) or passive (wind-driven) contactors that cycle through capture, conditioning, and regeneration stages to ultimately release CO_2 for purification and secure geologic storage or conversion. The Carbon Dioxide Removal (CDR) Program is maturing DAC processes, including solid sorbent, aqueous solvent, mineral looping, electrochemical, and membrane-based technologies coupled with secure geologic storage and conversion to long-lived products.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Applications are sought for the following subtopics:

a. Direct Air Capture Materials Durability Testing

DAC materials are exposed to air and typically undergo cyclical temperature, pressure, electrochemical and/or moisture swings to desorb CO_2 and regenerate the materials, which may result in eventual degradation and capacity fade. DAC material replacement costs can be significant, driving interest in durable materials that offer stable performance over thousands of DAC process cycles.[1] Gaining a better understanding of material degradation processes and identification of potential degradation products released into the environment by solvents and solid sorbents are also of interest. Past projects have evaluated the effects on material durability over a relatively limited set of operating conditions and durations. Thus, more information is needed on the mechanism and rate of degradation and durability of materials over significantly longer operating times to better inform techno-economic and life cycle analyses (TEA/LCA).[2]

Grant applications are desired for studies that will assess the longevity and degradation mechanisms of DAC advanced materials currently under development. Technologies developed from these grants may be implemented in future Regional DAC Hubs.

Applicants shall focus their applications on:

- Materials that have shown suitable performance as DAC materials in previous tests;
- Continuous testing of DAC materials in actual air for a minimum of 2,000 combined capture and regeneration cycles;
- Identification of any degradation mechanism(s) and product(s) and reporting of degradation rates under relevant DAC process conditions;
- Evaluation of potential material rejuvenation and recycling mechanisms based on feasibility, recovered performance, cost, and environmental impacts; and
- Preparing a preliminary TEA and LCA for a DAC process using the preferred material that incorporates the acquired test data.

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Questions – Contact: Richard (Mike) Bergen, richard.bergen@netl.doe.gov

b. Soil Carbon Monitoring for Enhanced Rock Weathering

Enhanced rock weathering (ERW) is a novel approach to carbon dioxide (CO_2) removal that utilizes existing pathways for the drawdown of CO_2 from the atmosphere. For example, rocks containing alkaline materials are exposed to the atmosphere through weathering processes, inducing a chemical reaction that consumes CO_2 and eventually locks it away in the form of solid carbonate materials. New approaches to accelerate the rate of this CO_2 drawdown focus on breaking down naturally-occurring alkaline materials, mine tailings, and industrial byproducts that can act as reactive species. The carbonate materials formed from these methods may have positive impacts on agricultural and coastal soil quality through fortification and de-acidification. However, they may also induce environmental harms through the introduction of dust into the air and toxic materials into the biosphere. Extensive studies of the durability of the carbonate materials and the impacts on soil quality are limited currently, as effective monitoring systems are actively being developed for this approach. [1,2]

Grant applications are desired for studies that will assess ERW approaches and tailored methods for soil carbon monitoring at climate relevant scales. The durability of carbonate storage and potential biosphere impacts are also of interest.

Applicants shall focus their applications on:

- Field studies to analyze effects of mineralogy, mineral particle size/reactive surface area, mineral application rate, rainfall, temperature, soil properties, plant-mineral interactions, and mineral pre-treatment steps on CO2 removal, with tailored quantification technologies incorporated;
- Development and deployment of soil carbon monitoring methods to efficiently establish baselines, evaluate real-time CO2 removal rates and permanence, and observe impacts on soil quality following ERW implementation;
- Development of an ERW process design and data-driven model;
- Analysis and quantification of ERW co-benefits and disbenefits;
- Analysis of pathways to integrate and/or co-optimize ERW and the extraction of critical minerals;
- Analysis of process scalability with consideration of feedstock availability, sourcing, transportation, and processing requirements; and
- Preparing a preliminary techno-economic analysis (TEA) and life cycle analysis (LCA) for the ERW process, including all upstream and downstream steps.

Questions – Contact: Richard (Mike) Bergen, richard.bergen@netl.doe.gov

c. Other

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

Questions – Contact: Richard (Mike) Bergen, richard.bergen@netl.doe.gov

References: Subtopic a:

1. X. Shi, H. Xiao, H. Azarabadi, J. Song, X. Wu, X. Chen, and K. S. Lackner, 2019, Sorbents for the Direct Capture of CO2 from Ambient Air, Angewandte, 59 (18), 6984-7006. https://doi.org/10.1002/anie.201906756 (October 24, 2023)

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2. M.-Y. A. Low, L. V. Barton , R. Pini and C. Petit, 2023, Analytical Review of the Current State of Knowledge of Adsorption Materials and Processes for Direct Air Capture, Chemical Engineering Research and Design, 189, 745-767. https://doi.org/10.1016/j.cherd.2022.11.040 (October 24, 2023)

References: Subtopic b:

1. M. Almaraz, N. L. Bingham, I. O. Holzer, E. K. Geoghegan, H. Goertzen, J. Sohng and B. Z. Houlton, 2022, Methods for Determining the CO2 Removal Capacity of Enhanced Weathering in Agronomic Settings, Frontiers in Climate, 4, 970429. https://doi.org/10.3389/fclim.2022.970429 (October 24, 2023)
2. S. Calabrese, B. Wild, M. B. Bertagni, I. C. Bourg, C. White, F. Aburto, G. Cipolla, L. V. Noto, and A. Porporato, 2022, Nano- to Global-Scale Uncertainties in Terrestrial Enhanced Weathering, Environmental Science & Technology, 56 (22), 15261–15272. https://doi.org/10.1021/acs.est.2c03163 (October 24, 2023)

C58-25. HYDROGEN TECHNOLOGIES

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

Currently, the most economical ways to generate clean hydrogen is through the use of fossil sources and sustainable biomass, combined with carbon capture, utilization, and storage. The Hydrogen with Carbon Management Program invests in research, development, and demonstration (RD&D) to gage whether carbon-based hydrogen as a fuel is a cost-competitive alternative to traditional fossil fuels. The program focuses on developing a new generation of carbon neutral or net-negative greenhouse gas emissions technologies, such as the gasification of wastes, reversible solid oxide fuel cells, hydrogen turbine technology, advanced materials, and sensors and controls.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Applications are sought for the following subtopics:

a. Advanced Thermal Barrier Coatings and Environmental Barrier Coatings for Ceramic Matric Composite

Higher operating temperature materials are clearly tied to advancing hydrogen turbines technology. DOE is generally interested in advancing Hydrogen Turbine technology through increased operating temperatures and efficiencies. DOE is generally interested in advancing the Environmental Barrier Coatings (EBC) and Thermal Barrier Coatings (TBC) to protect Ceramic Matric Composite (CMC) for use at elevated operating temperatures which would be applicable Hydrogen Turbines operating on 100% hydrogen environments. Grant applications are sought for research and development that develops Environmental Barrier and Thermal Barrier coatings applied to CMC surfaces operating at elevated temperatures, such as gas turbine or aero-engine parts, as a form of exhaust heat management. These 2-to-100-micron thick coatings of environmentally isolating and thermally insulating materials serve to protect CMCs from high water and hydrogen content gases and large and prolonged heat loads and can sustain an appreciable environmental and temperature differences between the load-bearing alloys and the coating surface. In doing so, these coatings can allow for higher operating temperatures while limiting the environmental and thermal exposure of CMC's, extending hydrogen turbine part life by reducing excessive oxidation and thermal fatigue. Due to increasing demand for more efficient engines running at higher temperatures with better durability/lifetime and thinner coatings to reduce parasitic mass for rotating/moving components, there is significant motivation to develop new and advanced EBC's and TBCs

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especially suitable for CMC's. Grant applications are sought for research and development that develops improved, innovative, and low-cost EBC's and TBCs for CMC's.

Questions – Contact: Adam Payne, adam.payne@netl.doe.gov

b. Impurity-Resistant SOEC Fuel Electrodes

In solid oxide cells (SOCs), hydrogen electrode catalyzes hydrogen oxidation reaction under Solid Oxide Fuel Cell (SOFC) mode and steam electrolysis under Solid Oxide Electrolysis Cell (SOEC) mode. For SOCs, nickel oxide is the most commonly used hydrogen electrode material due to its excellent catalytic activity, electronic conductivity, and wide availability. Nickel (Ni) is mixed with ionic conductors such as YSZ, GDC, or BZCY to form a cermet and expand the triple phase boundary (TPB) length. However, Ni can be susceptible to coking, agglomerate formation, and sulfur poising, and its performance would therefore be degraded notably by prolonged use at high steam concentrations and in the presence of contaminants originating from both intrinsic sources (in raw materials) and extrinsic sources (in gas flow), including impurities from water, CO2, H2O-CO2 mixtures, silicon from glass sealants, and sulfur. The performance and contaminant tolerance of Ni-based cermets can be enhanced by structural modification such as infiltration, in situ exsolution, and direct assembly of active and contaminant-tolerant components. Additionally, high-performance hydrogen electrodes require high porosity, high surface area, high-density TPBs, sufficient electrical and ionic conductivity, and high catalytic activity.

Grant applications are sought for research and development projects that have the potential for commercialization in the field of impurity-resistant SOEC fuel electrodes. Applicants must clearly outline what can cause the hydrogen electrodes to degrade during SOEC operation and how the techniques can be used to minimize the degradation. Applicants must clearly state how entire hydrogen electrode architectures would be fabricated and implemented, and why it would minimize the degradation under SOEC testing. A complete description of the manufacturing process required to achieve the proposed architectures should be provided to facilitate analysis of potential cost issues and implementation complexity, and Applicants must clearly state how they can overcome challenges related to the integration and scaling up of the proposed processes in SOFC/SOEC manufacturing where cost and throughput are critical to determine the economic viability of a technology.

Applications that focus on cathode electrodes and do not address the contaminants mentioned above will be considered non-responsive.

Questions – Contact: Evelyn Lopez, evelyn.lopez@netl.doe.gov

c. Other

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

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

References: Subtopic a:

1. Zhang, Hongye; Liu, Zhanwei; Yang, Xiaobo; Xie, Huimin, 2019, "Interface failure behavior of YSZ thermal barrier coatings during thermal shock", Journal of Alloys and Compounds, 779: 686-697, https://www.sciencedirect.com/science/article/abs/pii/S092583881834444X (October 24, 2023)

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2. Wei, Zhi-Yuan; Cai, Hong-Neng; Tahir, Adnan; Zhang, Wei-Wei; Li, Xue-Feng; Zhang, Yan; Huang, Ya-Ping; Liu, Yang, 2019, "Stress states in plasma-sprayed thermal barrier coatings upon temperature cycling: Combined effects of creep, plastic deformation, and TGO growth". Ceramics International, 45: 19829-19844, https://doi.org/10.1016/j.ceramint.2019.06.238 (October 24, 2023)
3. Tejero-Martin, D., et al., 2021, A review on environmental barrier coatings: History, current state of the art and future developments, Journal of the European Ceramic Society Volume 41, Issue 3, Pages 1747-1768, https://www.sciencedirect.com/science/article/pii/S0955221920308700 (October 24, 2023)

References: Subtopic b:

1. National Energy Technology Laboratory, REVERSIBLE SOLID OXIDE FUEL CELL (R-SOFC), National Energy Technology Laboratory, https://netl.doe.gov/coal/fuel-cells (October 24, 2023)
2. Pan, J., et al., 2021, Improving the activity and stability of Ni-based electrodes for solid oxide cells through surface engineering: Recent progress and future perspectives, Materials Report: Energy, https://www.sciencedirect.com/science/article/pii/S2666935821000379 (October 24, 2023)
3. Mogensen, M.B., et al., 2017, Relation Between Ni Particle Shape Change and Ni Migration in Ni–YSZ Electrodes- a Hypothesis, Special Issue: 12th European SOFC & SOE Forum, Volume 17 Issue 4, https://onlinelibrary.wiley.com/doi/10.1002/fuce.201600222 (October 24, 2023)
4. Shin, J.W., et al., 2019, Review on process-microstructure-performance relationship in ALD-engineered SOFCs, JPhys Energy, https://iopscience.iop.org/article/10.1088/2515-7655/ab30a0/pdf
5. He, S., et al., 2023, "A critical review of key materials and issues in solid oxide cells," Interdisciplinary Materials, https://doi.org/10.1002/idm2.12068 (October 24, 2023)

C58-26. CRITICAL MINERALS AND MATERIALS APPLICATIONS

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

Demand for critical minerals and materials (CMM), including the rare earth elements (REE), is anticipated to approximately quadruple by 2040 relative to today's production[1] largely due to the adoption and growth of clean energy technologies. In order to support U.S. domestic supply chain security, the U.S. Department of Energy's (DOE) Office of Fossil Energy and Carbon Management, Office of Resource Sustainability (FECM-30) Critical Minerals and Materials (CMM) program[2] is focused on producing CMM from unconventional and secondary feedstocks such as those derived from previous and sustaining coal mining operations, other fossil energy related byproduct streams (e.g., produced water from natural gas and oil operations), and other mining waste streams (e.g., mine tailings) to provide necessary materials for the clean energy transition. The CMM program is supporting the U.S. transition to a carbon-free economy and a domestic clean energy manufacturing industry by leading the federal government's efforts to characterize and assess domestic CMM resources from fossil energy byproducts and related resources.[3] By sourcing CMM from unconventional and secondary feedstocks, the United States is positioning itself to build a robust domestic circular economy. The DOE recognizes critical minerals as designated by the United States Geological Survey[4] and critical materials as designated by the DOE.[5]

Current mining methods generally require the removal and processing of host material that may be volumetrically 100's to 1000's of times greater than that of the target minerals or metals. Surficial mining operations often have geographical footprints on the order of several to tens of square kilometers, typically requiring the complete removal of surface vegetation and soil cover and construction of large permanent facilities such as tailings ponds. Additionally, exploration drilling for new deposits involves trucking or flying in heavy machinery to remote locations, potentially disturbing natural landcover, and exploration activities often take years to evolve into an active mine. The CMM program is seeking development of technology and methodologies that result in an overall significantly smaller footprint and reduced waste volume throughout the operations of CMM recovery and the development of technologies that reduce the cost and time associated with exploration activities such as through the reuse of existing wells or other boreholes. Ideally, these technologies and methodologies would support the advancement of more efficient targeted drilling by enabling real-time data gathering and processing through integrated drilling and characterization and would significantly decrease production of waste materials.

Research, Development, Demonstration and, Deployment (RDD&D) under the CMM program will create new methodologies, tools, and technologies required for identifying and assessing the quality (e.g., mineralogy, oxidation states, and impurities) and quantities of CMM available for sustainable, commercial, domestic production from a variety of unconventional and secondary resources. RDD&D under this program will also create new methodologies, tools, and technologies to recover from their host materials. Applications to this topic should seek to develop technologies capable of rapid subsurface characterization and development of methods or techniques for efficient and cost-competitive subsurface in-situ CMM beneficiation. The application of artificial intelligence/machine learning (AI/ML) to assist with development of these technologies or methodologies or the development of technologies or methodologies that are compatible with and accelerate use of AI/ML are highly encouraged.

All applications to subtopics under this topic must:

- Clearly provide understanding of current capabilities and outline the novelty of the proposed solution.
- Propose a tightly structured project which includes technical and business milestones that demonstrate clear progress, are aggressive but achievable, are quantitative, and culminate with development of a commercialized product.
- Clearly describe the commercialization potential of the federally-funded effort and provide a detailed path to scale-up in transition-to-industry practice.
- Fully justify the future potential for demonstration at a host site with an asset owner/operator who is an intended user.
- Prototype development and field demonstration is expected in subsequent phase(s).

All applications to subtopics under this topic should:

- Prioritize the recovery of critical materials required for the energy transition[4] as well as the reduction of waste materials and environmental impact due to the recovery process.
- Emphasize technologies that ensure safe, clean, and reliable recovery methods that meet or go beyond current environmental and safety standards.
- Clearly define the merit and the anticipated outcome of the proposed innovation compared to competing approaches including state-of-the-art.
- Be consistent with and have performance metrics (whenever possible) linked to published, authoritative analyses in your technology space.
- Include quantitative projections for price and/or performance improvement that are tied to representative values included in authoritative publications or in comparison to existing products.
- Fully justify all performance claims with thoughtful theoretical predictions and/or experimental data.
- Prioritize measurement and use of natural materials over synthetic materials.
- Partner with established industry to expedite acquirement of and access to test material(s), field test site(s), and any required permitting.

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Topics not of interest:

- Development of methods or techniques explicitly for use at or on the surface.
- Feedstocks consisting of recycled electronics, other e-waste, or geothermal brines.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Based on the guidelines above, grant applications are sought in the following subtopics:

a. Development of Novel Sensors and Instrumentation for Rapid Subsurface Characterization

Sensor and technology development to measure CMM concentrations in the field: This subtopic focuses on the development of tools and instruments that can be used for real-time in-situ characterization and quantification of CMM at depth. Tools to readily quantify CMM concentrations and or mode of occurrence are desired for down-hole settings (e.g. boreholes or existing wells). These tools may be developed for use during dynamic or static operations, e.g. a tool that may be deployed during drilling operations or after borehole completion or during in-situ, at-depth extraction operations. Tools and instruments developed under this subtopic should follow best practices regarding data and access security, be able to withstand potential hazards of downhole environments, and produce high-quality data technically comparable to or better than current industry standards.

Questions – Contact: Sandy Napolitano, sandy.napolitano@netl.doe.gov

b. In-Situ Extraction Methodologies and Technologies for Use in the Subsurface Environment

Assessment, development, and field demonstration of in-situ extraction technologies: Some sources of CMM that may currently be considered “non-mineable” by conventional standards are recoverable via in-situ extraction, otherwise known as in-situ leaching, in-situ recovery, or solution mining. Extraction techniques may involve microbial-based methods, including natural or designer microbes, ionic liquids, novel application of currently available solvents, or other means. Physical techniques may involve dissolution/replacement, CO2-enhanced recovery, high-pressure injection, subsurface reprocessing, or others. Whereas recovery of CMMs from these subsurface deposits may not be economically competitive in the present, anticipated future demand and improvements in recovery processes may provide favorable market conditions. Successful projects will develop methods or techniques for efficient in-situ extraction methodologies followed by at-depth field demonstration at a later phase.

Questions – Contact: Sandy Napolitano, sandy.napolitano@netl.doe.gov

c. Other

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

Questions – Contact: Sandy Napolitano, sandy.napolitano@netl.doe.gov

References:

1. IEA, 2021, The Role of Critical Minerals in Clean Energy Transitions, IEA, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (October 24, 2023)
2. Montross, S. N., Bagdonas, D., Paronish, T., Bean, A., Gordon, A., Creason, C. G., et al., 2022, On a unified core characterization methodology to support the systematic assessment of rare earth elements and

critical minerals bearing unconventional carbon ores and sedimentary strata. Minerals, 12(9), 1159, https://doi.org/10.3390/min12091159, (October 24, 2023)
3. Communications and Publishing, 2022, U.S. Geological Survey List of Critical Minerals, USGS, https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals (October 24, 2023)
4. U.S. Department of Energy, 2023, U.S. Department of Energy Releases 2023 Critical Materials Assessment to Evaluate Supply Chain Security for Clean Energy Technologies , U.S. Department of Energy Critical Materials Assessment, https://www.energy.gov/eere/articles/us-department-energy-releases-2023-critical-materials-assessment-evaluate-supply (October 24, 2023)

C58-27. CARBON ORE PROCESSING

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

Coal and coal wastes are domestic resources that have contributed to U.S. economic growth for over a century. However, in a shifting energy generation paradigm, innovation is needed to extract the full economic value from these resources. The Carbon Ore Processing Program addresses this need by supporting R&D to commercialize a spectrum of coal derived products, ranging from high volume through high value. The program supports R&D for uses of coal and coal wastes that are exclusive of traditional thermal and metallurgical applications.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Grant applications are sought for the following subtopic:

a. Direct Use of Coal or Carbonaceous Coal Wastes as Lithium-Ion Battery Anodes

Demand for graphite has soared as the nation undergoes a transformational shift to a clean energy economy [1]. Graphite demand will continue to increase as lithium-ion battery production scales for battery electric vehicles and other clean energy technologies such as grid-scale battery storage. The positive demand slope has created volatility and increased prices in both synthetic and natural graphite markets and has increased US clean energy manufacturers' reliance on imported graphite. While the Carbon Ore Processing Program maintains active R&D in the production of graphite from coal and carbonaceous coal-waste, it is recognized that lithium-ion batteries could see a more significant cost decrease if coal or carbonaceous coal waste could be used directly as an anode material [2].

Grant applications are sought for research and development on the direct use of coal or carbonaceous coal-wastes as an anode material in lithium-ion batteries. While mild cleaning and mild heat treatments are acceptable, technical approaches should **not** include significant feedstock upgrading (e.g. solvent extraction or hydrogenation) or intensive heat treatments (e.g. graphitization). The anode carbon must be more than 50% coal or carbonaceous coal-waste, by weight. Approaches may add other forms of carbon or performance modifiers (e.g. silicon) to the anode, subject to the previously stated 50% weight requirement. Use of conventional anode graphite with the addition of small amounts of coal-derived carbon (e.g. nanotubes, graphene, graphite, carbon fiber, etc…) is **not** of interest under this topic.

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Proposed R&D should identify the coal or carbonaceous coal-waste material, discuss any necessary pre-treatments or performance enhancing additives, and describe how lithium-ion battery anodes will be produced from the material (including any ES&H concerns associated with trace species in coal or carbonaceous coal wastes). The Phase I work scope should enumerate performance targets such as specific energy, cycle stability, fast-charge capability, cost, and whether the anode material is amenable to next-generation dry electrode processing (i.e. n-methyl-pyrrolidone free processing). Phase I work should also, if practicable, culminate in a test of the best-demonstrated material combination in a full cell using an industrially relevant form factor (e.g. 18650). Phase I work should also include preliminary life cycle analysis (LCA) and techno-economic analysis (TEA) to understand how process emissions and economics compare to conventional graphite, respectively. Proposed technologies should, to the greatest extent practicable, utilize commercial off the shelf processing technology to minimize technological risk and development time.

Applicants shall focus their proposals on:

- Describing, in sufficient detail to allow for evaluation, the process by which coal or carbonaceous coal-waste is processed, treated, or prepared as an anode material for lithium-ion batteries
- Describing a test campaign to determine whether the coal or carbonaceous coal waste based lithium-ion battery anode meets the technical properties (performance) required for commercialization
- Technologies that yield anode material for lithium-ion batteries utilizing an economically feasible and scalable process
- Technologies that, to the greatest extent practicable, utilize commercial off the shelf processing technology
- Outlining a preliminary techno-economic analysis (TEA) to be completed during Phase I
- Outlining a preliminary life cycle analysis (LCA) to be completed during Phase I
- Addressing ES&H concerns surrounding the handling of carbon nano-materials, contaminants (trace species), and off gasses

Questions – Contact: Christian Robinson, Christian.Robinson@netl.doe.gov

b. Other

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

Questions – Contact: Christian Robinson, Christian.Robinson@netl.doe.gov

References:

1. A. Stewart, 2023, "Graphite (Natural)," U.S. Geological Survey, Mineral Commodity Summaries, USGS, https://www.usgs.gov/centers/national-minerals-information-center/mineral-commodity-summaries (October 24, 2023)
2. J. Abou-Rjeily et al., 2019, "Bituminous Coal as Low-Cost Anode Materials for Sodium-Ion and Lithium-Ion Batteries," Energy Technology, vol. 7, no. 7, https://onlinelibrary.wiley.com/doi/full/10.1002/ente.201900005 (October 24, 2023)

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C58-28. ADVANCED REMEDIATION TECHNOLOGIES

Maximum Phase I Award Amount: $250,000	Maximum Phase II Award Amount: $1,600,000
Accepting SBIR Phase I Applications: YES	Accepting STTR Phase I Applications: YES
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

The Advanced Remediation Technologies Program portfolio carries out research that supports the development of technologies to reduce or eliminate environmental impacts associated with the production of fossil energy resources such as oil and natural gas. Recognizing that oil and natural gas resource development will continue during the ongoing energy transition to cleaner fuels, research in this area is directed toward finding ways to reduce the risks of environmental impacts during exploration, well drilling, completion, and production operations.

For this topic, the National Energy Technology Laboratory is not eligible to act as a subawardee.

Applications are sought for the following area(s):

a. "Proof of Concept" Approaches for Advanced Characterization Tools for Assessing Natural Gas and Thermal Energy Co-Production Potential

As of 2021, there are approximately 916,934 oil and natural gas producing wells in the United States. Of the producing wells, approximately 750,969 wells are known as conventional while the remaining 165,965 wells known as horizontal (unconventional) wells. As horizontal drilling and completion technologies have advanced, the majority of oil and natural gas production in the United States has come from these increasing number of horizontal wells.

As oil and natural gas wells mature, their production volumes decrease. These wells become less economical to operate and are potentially at risk of becoming "orphaned" (An orphaned well is defined as an unplugged, abandoned well for which no owner or operator has been identified.) Many conventional wells end up becoming "marginal" producers as they fall below output levels of 15 barrels of oil equivalent per day (BOE/d) or 90 thousand cubic feet per day (MCF/d) of natural gas. These wells account for approximately 80% of all producing wells, but only 7% of production in the United States.[1]

Leveraging marginal wells as an opportunity for the co-production of thermal energy from the reservoir could provide a supplemental revenue stream to support continued operation and maintenance of these resources, reduce the likelihood of future improper well abandonment, and represent an opportunity for future optimization and repurposing of existing oil and natural gas infrastructure for full-scale geothermal energy production. Each of these elements improves the environmental performance of marginal resources, reduces the likelihood of methane emissions from abandoned infrastructure, and accelerates the future energy transition with the decarbonization of fossil fuel-based energy assets.[2]

Further reservoir characterization is needed to better determine whether marginal, idled, or orphaned oil and natural gas wells have to be plugged and abandoned to prevent methane leakage to the atmosphere and other sensitive receptors, or whether the valuable infrastructure can be repurposed for environmental benefit.[3]

The challenges of effective reservoir characterization for natural gas and thermal energy co-production become more difficult the deeper a well is drilled. Below 15,000 feet, temperatures can top 400 °F (205 °C) and pressures can exceed 10,000 psi. Such downhole conditions can disrupt or disable reservoir characterization tools and other critical sensors needed to accurately determine wellbore integrity and viability, reservoir condition, and

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geomechanical/geochemical data needed for effective well completion, reservoir management, and energy resource co-production. Developing and refining the electronic tools that can function under these difficult conditions can accelerate the use of deep natural gas reservoirs as future potential geothermal resources.

In order to better determine the viability of resource co-production and future energy asset transformation, advanced sensing platforms are needed to better align oil and natural gas infrastructure with subsurface thermal energy resources. These sensing platforms must be capable of continuous operation in high-temperature and high-pressure environments to ensure that viable robust reservoir characterization data and information are available for dissemination.

Research advanced from "proof of concept" maturity levels are sought for advanced sensing technologies, sensors or sensor arrays, and advanced modeling of co-produced natural gas and thermal energy resources. In addition to sensor development, advanced simulation, artificial intelligence, or machine learning approaches to determine the effectiveness of thermal energy co-production from both conventional and unconventional wells in both "low-grade" and more traditional thermal gradient environments is desired.

The ultimate intent of the research requested is to explore the current capabilities of existing equipment or approaches and build upon the current "state of the art" for reservoir characterization to better inform and accelerate natural gas and thermal energy co-production for future development of processes or mechanisms to determine thermal energy co-production potential as a multi-scale approach (well-to-field-to-play-to-basin), and eventually conduct both laboratory and field validation testing on the technologies, tools, and processes that are matured through the research, development, and demonstration process.

1. Reservoir Characterization Tools: Physical and digital advanced real time sensors or array of sensors for "real-time" reservoir characterization and continuous monitoring related to the co-production of natural gas and thermal energy resources in both "low-grade" and higher temperature environments.
2. Advanced Modeling and Simulation Tools: Cognitive and high-performance models or simulations utilizing artificial intelligence, machine learning, or other advanced analytics that can determine multi-scale, resource co-production potential as well as analyze large volumes of data in real time to inform decision making processes related to flow rates, wellbore pressures, and loss of heat to surrounding formations as natural gas is produced.
3. Wellbore Integrity Tools: Surface or borehole deployable tools for determining the integrity of all well casing elements (including liners and production casing) and the wellbore annulus (including cement and casing support elements) for natural gas and thermal co-production, with particular interest in well/wellbore integrity determination in higher temperature environments, where casing and cementitious materials could degrade more quickly than a "typical" natural gas producing well.[4]

Questions – Contact: Eric Smistad, eric.smistad@netl.doe.gov

b. Produced Water Optimization – PARETO

In 2021 the US Department of Energy (DOE) launched a three-year, $5 million produced water (PW) optimization initiative to develop, demonstrate and deploy a novel optimization framework for PW management, recycling, and beneficial reuse. Specifically, PARETO supports decision-makers with: (1) PW management, including infrastructure buildout recommendations and coordination of PW deliveries; (2) PW treatment, including treatment facility placement recommendations and selection of effective treatment technologies (3) PW beneficial reuse, including identification of beneficial reuse options and distribution of treated PW or concentrated brine.

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DOE is offering an SBIR grant as an accelerant to the adoption of PARETO as a commercial tool to enhance the management of PW. Project PARETO is an award winning [1], DOE sponsored produced water (PW) management software platform developed by the National Energy Technology Laboratory in partnership with Lawrence Berkeley National Laboratory (LBNL) the Ground Water Protection Council (GWPC) Carnegie Mellon University, and Georgia Tech University [2]. PARETO was designed with a twofold objective of reducing the impact of the oil and gas sector on US waters and reducing industry operating costs [3]. If large-scale industry adoption of the tool can be achieved and supported, PARETO will help maintain a secure, low-impact, and cost-effective energy supply within the United States [4].

PARETO has been developed as free and open-source software for industry benefit. Nevertheless, industry adoption must have support to ensure that users continue to use PARETO into the future. This means that a third party will adopt the software and develop a service model, becoming the industry hub for support. Commercialization remains the intended future of PARETO, and while this business model has proven viable, there remains substantial risk borne by the entity seeking to commercialize the software. The SBIR grant would substantially alleviate that risk, increasing the likelihood of a successful start-up and industry adoption of PARETO software.

The PARETO framework is provided as a downloadable executable program or as source code . Beyond the software itself, this initiative will complete a series of detailed case studies with industry and other partners . DOE announces the SBIR to evaluate the PARETO framework in an industrial fashion. Awardees should use PARETO framework and contribute to this tool by:

- Build an interface between industrial data sets and PARETO framework (i.e., google earth pro, GIS data, etc.).
- Develop a demonstration study leveraging PARETO with industrial data.
- Document a series of case studies within different basins and field testing of the systems are to be field tested or demonstrated during Phase II, and sites are to be found in Phase I to demonstrate PW management in the field.
- Phase II would include a real demonstration in the field of the whole physical systems of water management.

Questions – Contact: Eric Smistad, eric.smistad@netl.doe.gov

c. Other

In addition to the specific subtopics listed above, grant applications in other areas relevant to this topic are invited. Submissions under this subtopic will be evaluated for responsiveness with respect to current Office of Fossil Energy and Carbon Management mission priorities.

Questions – Contact: Eric Smistad, eric.smistad@netl.doe.gov

References: Subtopic a:

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3. L. Santos, A. D. Taleghani and D. Elsworth, 2022, "Repurposing abandoned wells for geothermal energy: Current status and future prospects," Renewable Energy, vol. 194, pp. 1288-1302, https://www.sciencedirect.com/science/article/abs/pii/S0960148122007959 (October 24, 2023)
4. P. Allahvirdizadeh, 2020, "A review on geothermal wells: Well integrity issues," Journal of Cleaner Production, p. 275, https://www.sciencedirect.com/science/article/pii/S0959652620340543 (October 24, 2023)

References: Subtopic b:

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2. M. G. Drouven, A. J. Calderon, M. A. Zamarripa and K. Beatti, 2022, "PARETO: An open source produced water optimization framework," Optim. Eng., vol. 24, p. 2229–2249, https://doi.org/10.1007/s11081-022-09773-w (October 24, 2023)
3. M. McEwen, 2022, "Texas and New Mexico water consortiums working with Department of Energy on produced water research," Midland Reporter-Telegram, 20 8 2022, https://www.mrt.com/business/energy/article/Federal-Texas-New-Mexico-groups-work-on-produced-17386886.php (October 24, 2023)
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5. Project-pareto, 2023, https://github.com/project-pareto (October 24, 2023)

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PROGRAM AREA OVERVIEW: OFFICE OF NUCLEAR ENERGY

The primary mission of the Office of Nuclear Energy (NE) is to advance science and technology to meet United States (U.S.) energy, environmental, and economic needs.

NE has identified the following four goals to address challenges in the nuclear energy sector, help realize the potential of advanced technology, and leverage the unique role of the government in spurring innovation:

(1) Enable continued operation of existing U.S. nuclear reactors;
(2) Enable deployment of nuclear reactors;
(3) Develop advanced nuclear fuel cycles; and
(4) Maintain U.S. leadership in nuclear energy technology.

Collectively, all NE-sponsored activities support the Department's priorities to combat the climate crisis, create clean energy jobs with the free and fair chance to join a union and bargain collectively, and promote equity and environmental justice by delivering innovative clean energy technologies for nuclear energy systems.

All applications submitted under this Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR) Funding Opportunity Announcement (FOA) must demonstrate a strong tie to at least one of the four NE goals and highlight how it supports the Department of Energy (DOE) priorities.

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

For additional information regarding NE's goals and priorities, click here.

C58-29. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

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

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

Grant applications are sought in the following subtopics:

a. Advanced Modeling and Simulation

Computational modeling of nuclear reactors for design and operation is becoming increasingly predictive and able to leverage high-performance computing architectures. While these tools perform similarly to legacy tools for simple problems, utilizing the advanced features of these tools requires more in-depth training, skills, and knowledge. Furthermore, to integrate robust multi-physics capabilities and current production tools for ease-of-use and deployment to end users, and for enabling the use of high-fidelity simulations to inform lower-order models for the design, analysis, and licensing of advanced nuclear systems and experiments, it is worthwhile to invest in technologies that ease the adoption of these modern computational tools.

Applications are sought that apply NE's advanced modeling and simulation tools (https://neams.inl.gov/code-descriptions/) to industry problems for increased use by industry, either light- water reactor (LWR) or non-LWR reactor industry.

This can include:

- Facilitate access to NE's advanced modeling and simulation tools for inexperienced users;
- Apply the results of high-fidelity simulations to inform the improved use of lower-order models for improved use of fast-running design tools;
- Provide capabilities for automated verification of numerical solutions, including mesh refinement studies; and
- Use of the tools with existing plant operational data to demonstrate the value for real-world industry applications.

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

b. Advanced Methods and Manufacturing Technologies (AMMT) Program

Advances in nuclear energy technologies critically depend on high-performance materials that can withstand harsh environmental conditions in nuclear reactors. The advances of new manufacturing technologies open up new opportunities for the design of innovative materials with improved properties beyond what are achievable with traditional manufacturing techniques. Applications are sought to develop new, high-performance materials enabled by advanced manufacturing for nuclear energy applications. Of particular interest is the design of new materials that exploit the unusual characteristics of additive manufacturing processes to create materials with enhanced performance. A broad range of materials for nuclear energy systems will be considered, including iron-based alloys, nickel-based alloys, high entropy alloys, refractory alloys, composites, or functionally graded materials. The new materials must demonstrate one or more of high-temperature properties, radiation, and corrosion resistance relative to existing reactor materials, in a way that is significantly improved. The stability of microstructure and properties during long service life should also be demonstrated through accelerated testing and/or model predictions. The goal is to strengthen the pipeline of new materials that can make advanced nuclear reactors and the current fleet more resilient and economically competitive.

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

c. Nuclear Science User Facilities (NSUF) Program

The NSUF program has strong interest in the development of new and advanced techniques that will enable cutting edge and more cost-effective studies related to irradiation effects in nuclear fuels and materials. Irradiation embrittlement due to long-term and high-energy neutrons is a major concern for reactor pressure vessel (RPV) materials degradation in LWRs, causing mechanical property changes such as increase of hardness, yield stress, and tensile strength, and decrease of toughness. Consequently, many reactors include capsules containing representative steels that are located on the inside of the RPV for several years before their fracture toughness is determined by destructive Charpy impact testing. Alternative, non-destructive methods for directly assessing material embrittlement of in-situ RPV material under operating service conditions due to irradiation are desirable. Applications are sought focused on developing in-situ sensors and detectors and diagnostic equipment for embrittlement testing under extreme reactor environments of high temperature, radiation, and pressure. For more information on the NSUF program visit https://nsuf.inl.gov/

Questions – Contact: Christopher Barr, christopher.barr@nuclear.energy.gov

d. Advanced Sensors and Instrumentation (ASI) (Crosscutting Research)

Applications are sought for the ASI program regarding the development of innovative technologies that support: the existing fleet of nuclear reactors, including materials test reactors; the development of advanced reactor concepts and the acceleration of advanced fuel cycle technology commercialization. The proposed technologies should demonstrate greater accuracy, reliability, resilience, higher resolution, and ease of replacement/upgrade capability for applications in the nuclear environment, while striving to reduce operations and maintenance (O&M) costs. The proposed technology should be applicable to multiple reactor concepts or fuel cycle applications, i.e., crosscutting.

Applicants should focus on the following areas:

- Develop and demonstrate innovative sensors and instrumentation that can reliably operate in the nuclear reactor core, primary and secondary coolant loop, or other relevant plant systems. All sensors/instrument technologies should be developed to be operable with consideration for harsh environmental conditions (i.e., temperature, pressure, corrosion, radiation). Irradiation experiments in Material Test Reactors, including University Research Reactors, should be considered as the preferred method for the technology demonstration and the definition of design requirements for near term deployment. The following are some examples of technical areas of interest: distributed or multi-point measurement of operational conditions (neutron and gamma-ray flux, temperature, pressure, fission gas products, fluid flow rate) or material behavior (stress/strain, deformation, thermal conductivity).
- Advanced control systems that increase nuclear plant system reliability, availability, and resilience including the ability to detect and manage faults in instrumentation and control (I&C) systems and plant components; state of the art control rooms, control systems, and plant control technologies. The project outcomes must enable semi-autonomous and remote operation, and advanced automation.
- Enhancement of instrumentation and advanced control systems performance using artificial intelligence, machine learning application or digital twins. The goal and intent should be the demonstration of these methods and experimental validation showing tangible benefits (i.e., improved performance, reduced cost, etc.).

Applications that address the following areas are NOT of interest for this subtopic and will be declined unless crosscutting capabilities are demonstrated as part of the submission: nuclear power plant security (e.g., cyber, physical, etc.); homeland defense or security; reactor building/containment enhancements; radiation health physics dosimeters (e.g., neutron or gamma-ray -detectors); radiation/contamination monitoring devices; U. S. Nuclear Regulatory Commission (NRC) probabilistic risk assessments or reactor safety experiments, testing, licensing, and site permit issues; special nuclear materials (SNM) monitoring and non-proliferation; technologies that support nuclear weapons research & development.

Questions – Contact: Daniel Nichols, daniel.nichols@nuclear.energy.gov

e. Component Development to Support Liquid Metal Reactors – Electromagnetic Pumps

Liquid metal reactors have been demonstrated in a number of countries. Advanced versions of these first-generation reactors attempt to simplify the large pumps by utilization of electromagnetic pumps that have the ability to operate submerged at high temperature, and under irradiation.

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DOE is seeking applications from a U.S. company or companies to advance liquid metal reactors and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Development of insulation technology for electromagnetic pumps that can withstand high temperatures and gamma and neutron radiation during liquid metal reactor operations.
- Development of a small electromagnetic pump that could be tested in a high temperature prototypic sodium environment.

Questions – Contact: Kaatrin Abbott, kaatrin.abbott@nuclear.energy.gov

f. Roller Bearings for High Temperature Sodium Applications

Liquid metal reactors have been demonstrated in a number of countries. Advanced versions of these first-generation reactors attempt to reduce the cost of the primary heat transport system by utilization of advanced robotic refueling systems. Advanced robotic refueling systems allow for the reduction in the reactor vessel size and thus a reduction in overall costs of the reactor plant. A number of these advanced refueling systems use mechanisms such as gears, roller bearings, ball screws, universal joints, and other mechanical components in liquid metals at high temperatures. These advanced refueling system will be used at about 350°C sodium temperature to refuel the reactor (when the reactor is shutdown). The ultimate goal is to leave these advanced refueling systems in a parked static position in the reactor vessel when the reactor is operating at 520°C sodium outlet temperature and high neutron and gamma radiation.

DOE is seeking applications from a U.S. company or companies to advance liquid metal reactors and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Development of roller bearings for use in refueling systems - both radial, thrust, and combined radial and thrust bearings are of interest. For example, the target materials of construction for bearings are Inconel 718 races and stellite (6B or similar) rolling elements.

Questions – Contact: Kaatrin Abbott, kaatrin.abbott@nuclear.energy.gov

g. Under-lead Viewing Systems for Advanced Reactor Applications

Liquid metal reactors have been demonstrated in a number of countries. Countries have used various liquid metal coolants such as sodium, sodium-potassium alloy, and lead. One of the important maintenance items for advanced reactors is to perform in-service inspection periodically of systems and components that are submerged inside the reactor vessel coolant. The coolants for these liquid metal reactors are opaque and thus non-optical methods need to be developed and used when performing these inspections.

DOE is seeking applications from a U.S. company or companies to advance liquid metal reactors and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Development of under-lead viewing system for performing in-service inspection of reactor vessel internal structures.

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Questions – Contact: Kaatrin Abbott, kaatrin.abbott@nuclear.energy.gov

h. Rapid, Inexpensive Molten Salt Property Measurement

Developing adequate understanding of the behavior of molten salt reactors (MSR) under both normal and accident conditions is dependent on adequate understanding of molten salt properties. DOE-NE is developing a database collecting molten salt thermophysical and thermochemical properties, however there are still numerous data missing. Measuring molten salt properties is currently expensive and time-consuming. Molten salts are hot, can be corrosive, may include volatile components, are frequently hydroscopic, and can be both toxic and intensively radioactive, substantially increasing the difficulty of each of the steps in performing adequate quality measurements. Moreover, the measurements can be significantly impacted by sample purity at levels resulting from environmental contamination.

DOE is seeking applications from a U.S. company or companies to advance molten salt property measurement technology and foster growth for U.S. industry.

Development of innovative property measurement tools and techniques that decrease the time and expense of conventional measurement methods are encouraged. Potential areas for sensor development and candidates for collaboration include but are not limited to:

- Oxygen concentration
- Moisture content
- Viscosity
- Thermal diffusivity
- Phase development and precipitation
- Heat capacity
- Density
- Vapor pressure
- Surface tension
- Emissivity
- Melting point

Questions – Contact: Janelle Eddins, Janelle.Eddins@nuclear.energy.gov

i. Advanced Construction Technology (ACT) Initiative

Various studies of nuclear energy economics have identified the major role of construction costs and schedule risks in driving up the costs of nuclear power plants. (e.g., *The Future of Nuclear Energy in a Carbon-Constrained World*, Massachusetts Institute of Technology 2018; *The ETI Nuclear Cost Drivers Project: Summary Report*, Energy Technologies Institute (ETI), 2018; *Advanced Nuclear Technology: Economic-Based Research and Development Roadmap for Nuclear Power Plant Construction*, Electric Power Research Institute (EPRI), 2019.) Through its ACT Initiative, the National Reactor Innovation Center (NRIC) seeks to develop and demonstrate technologies, processes, and approaches that would mitigate construction risks and improve construction outcomes through improved project management, advanced technologies, manufacturing approaches, and/or supply chain improvements.

Applications are sought that identify, evaluate and/or develop methods, processes, or technologies that can significantly improve advanced nuclear construction cost and schedule outcomes by addressing key challenges identified in literature or projects. These could include approaches to project management, digital engineering, open architecture design, construction technologies, manufacturing approaches, etc. Proposed

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activities should not be duplicative of activities currently being pursued through the NRIC ACT Initiative. For more information on the ACT Initiative please visit: https://nric.inl.gov/advanced-construction-technologies-initiative/

Questions – Contact: Savannah Fitzwater, savannah.fitzwater@nuclear.energy.gov

j. Robotics for Advanced Nuclear Facilities

NRIC seeks to develop and demonstrate mobile robotic technologies that will provide for more economical and safer advanced reactor plants including fuel handling systems. Robotic systems have the potential to reduce human exposure to radiological and industrial hazards, improve quality, improve efficiency and aid in emergency response.

Grant applications are requested for modifying existing robotic platforms or developing and demonstrating robotic systems that can:

- Support operations and inspections by automating daily plant rounds, performing inspections in confined space or other hazardous areas, performing general inspections, etc.
- Support fuel management such as providing fueling and defueling capability for advanced reactors.
- Assist in emergency response to avoid endangering humans.
- Perform maintenance tasks such as filter replacements or liquid metal valve replacements.

In addition, grant applications are requested for modifying existing or developing new robotics that can withstand:
Radiation levels found in and around advanced nuclear reactors.
Temperature and pressure conditions present in nuclear plants including the conditions found in helium cooled and liquid metal cooled reactors.

The application should clearly outline the benefits of the proposed system such as new capability not currently done by humans, improved safety, reduced costs, improved quality, etc.

Questions – Contact: Savannah Fitzwater, savannah.fitzwater@nuclear.energy.gov

k. Supporting Technologies for Microreactor Operations

The Office of Nuclear Energy supports activities to enable the development, demonstration, and commercialization of a variety of microreactor concepts. Key to demonstrating and commercializing these concepts, is development of supporting capabilities such as transportation, defueling, and shielding technologies.

To help support advanced reactor demonstration and commercialization, NRIC is establishing the Demonstration and Operation of Microreactor Experiments (DOME) test bed which will be capable of hosting critical reactor experiments that operate at less than 20MWt using High Assay Low Enriched Uranium (HALEU) fuel. These tests and experiments will require many support systems. Transporting fueled reactors, shielding reactors during shipping and testing, and fueling/defueling reactors pose unique problems during demonstration of these systems.

Applications are requested for developing and demonstrating fueling/defueling systems, advanced modular shielding, and innovative transport options for microreactors that are fueled by HALEU fuel.

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Questions – Contact: Savannah Fitzwater, savannah.fitzwater@nuclear.energy.gov

l. Microreactor Applications, Unattended Operations, and Cost-Reduction Technologies

Improvements and advances are needed in support of novel applications, unattended operations, and cost reduction technologies that support wide-spread deployment of microreactors. Microreactors are a crosscutting class of very small reactors that are factory fabricated, transportable, and self-regulating.

Microreactors are not defined by power output, but in most cases produce on the order of ones to tens of megawatts-electric. Given their size, they are ideal for novel applications that are “off-grid by circumstance”: those which require substantial local power to areas where either there is no grid access or where fuel transportation is challenging/ undesirable, such as remote communities, resource extraction sites, Electric Vehicle charging stations, and disaster relief sites. Microreactors are ideal as well for applications which are ”off-grid by design”: those which require highly reliable power or local ownership/control of the power source, such as hospitals, data centers, airports, shipping ports, desalination plants, manufacturing facilities, industrial and district heating, and other critical infrastructure which may be vulnerable to natural or intentional disruption.

There is a strong desire to improve integration with applications, reduce costs, and enable wider use of microreactor technology. Therefore, this topic seeks new and innovative technologies that support microreactor deployment or application integration in the following areas:

- Civilian applications requiring 100’s of kW to MW-scale power in the form of heat or electricity to support remote or non-remote uses. These applications should specifically highlight the need and value of having a reliable source of energy provided by microreactors and have significant potential market opportunities. These applications should represent the utilization of the energy, not generation.
- Technologies that support unattended and remote operations of microreactors and minimize on- site highly trained personnel, operators, and maintenance staff. The technologies should not be microreactor design-specific but may need to consider the operational characteristics of microreactors. Ultimately, the staffing targets for microreactors are 0.5-1.5 FTE/MW.
- Technologies that can result in significant reductions in microreactor costs that can expand their applications by increasing their competitiveness with other energy sources. The technologies should not be microreactor design-specific but should provide microreactor hardware, system, and operation cost reductions.

Applications that address the following technology development areas are NOT of interest for this subtopic and will be declined: new microreactor concepts, non-civilian applications of microreactors, radioisotope power source applications.

Questions – Contact: Diani Li, Diana.Li@nuclear.energy.gov

m. Graphite Component Development to Support High Temperature Gas Reactors (HTGR) and Molten Salt Reactors (MSR)

HTGRs and MSRs often employ graphite core components, typically to perform neutron moderation and economy and structural support-related functions.

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DOE is seeking applications from a U.S. company or companies to advance HTGRs and MSRs and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Develop graphite core component non-destructive examination (NDE) X-ray computed tomography (XCT) system to assay large graphite components. Key performance needs are rapid processing and resolution down to 1 mm^3.
- Develop in-situ visual and eddy current NDE inspection technology for HTGR graphite components. Key performance needs are rapid processing, radiation hardened hardware, and resolution down to 500 microns.
- Develop in-situ NDE visual and eddy current MDE inspection technology for MSR graphite components, such as those in pebble bed fluoride salt-cooled reactor designs.
- Develop technology for cleaning used graphite components to enable reduced radioactive waste classification or reuse of materials.

Questions – Contact: Matt Hahn, Matthew.Hahn@nuclear.energy.gov

n. Thermal Hydraulic Development to Support High Temperature Gas Reactors (HTGR)

HTGRs involve complex and novel thermal hydraulic conditions, such as gas flows through a pebble bed and helical coil steam generators.

DOE is seeking applications from a U.S. company or companies to advance HTGRs and foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Analyze helical coil steam generator stability, with focus on low-power and startup conditions. Such analyses could employ 1D system codes to analyze design-specific challenges, including discrepancies between idealized and actual heat profiles, multiple instability modes beyond density wave oscillations, and accounting for variations in shell-side flow and temperature distribution.
- Develop pebble bed reactor reflector thermal analysis approach that emphasizes the near-wall region of the pebble bed. Such an approach could characterize heat transfer among gas, pebbles, and wall/reflector components under various normal and accident conditions, such as loss of forced circulation. The interface of the pebble bed and reflector materials is the primary interest, and numerous benefits could be achieved by modeling the multiple modes of heat transfer involved (conduction, convection, radiation, and dispersion).

Questions – Contact: Matt Hahn, Matthew.Hahn@nuclear.energy.gov

o. Reducing the Footprint and Cost of Structure and Siting for Distributed Nuclear Generation

DOE is seeking applicants to develop concepts for integrating advanced nuclear reactors into both existing sites and new construction or developments. Innovative system integration and design is needed to reduce the cost and footprint for integrating advanced nuclear reactors in close proximity to industrial or commercial applications. Concepts will be developed taking into account common design requirements that require established regulations or make a case for updating regulations.

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The applicant should develop design requirements, with consultation or review of available data from a variety of reactor vendors, that account for physical space and structures required to install, contain, maintain, operate, and control the reactor, turbines, fuel storage and handling systems, cooling components, thermal and electrical distribution systems, emergency power and fire protection equipment, safety and physical security systems, and plant access and parking by road or rail as necessary. Utilizing publicly available or calculated specifications for the reactor, the applicant will develop generic design requirements for installing a reactor addressing regulatory or suggested modified regulatory requirements, safety, operations, control, and maintenance. The applicant will use existing plans and drawings for an integrated industrial plant, neighborhood, and/or large building or campus to demonstrate the feasibility of integrating an advanced reactor into these locations while meeting design requirements. Three dimensional renderings will be used to demonstrate the final design concept, with views that highlight the design aspects that address requirements. The final product will include rationale for any modifications needed to regulatory requirements.

Questions – Contact: Jason Marcinkoski, Jason.Marcinkoski@nuclear.energy.gov

p. Cost to Manufacture and Install Advanced Nuclear Reactor Technologies

Nuclear reactors are an attractive technology to power multiple applications, particularly hydrogen, synthetic fuels, polymers, chemicals, minerals production, refineries, and district heating, where clean, reliable energy, or high-quality heat is needed with very high availability. Nuclear reactors offer the ability to provide heat and electricity at the location where it is needed, greatly reducing the cost to transmit/distribute energy. For commercial deployment in these areas, it is critical for nuclear reactors to provide a competitive cost of heat and electricity with incumbent and advanced technologies with no compromise in durability and robustness of designs. Cost is one of the fundamental drivers for enabling commercialization of technologies.

Proposed projects should define the current state-of-the-art in key areas, develop and refine system configurations and designs over time, and identify technology gaps. Cost analysis should identify manufacturing and construction efficiencies and economies of scale based on production rates ranging from 5 GW/year to 30 GW/year.

DOE recognizes that third party cost analysis will have limited access to proprietary information and cannot be leading experts in all aspects of the work, thus applications should include opportunities and mechanisms to obtain up to date information from commercial industry as a whole and subject matter experts in industry and research communities.

Applications are sought for the development of cost analysis focusing on reactor manufacturing cost and reactor installation cost:

Reactor and Auxiliary Component Costs—Proposed projects will develop a detailed reference design that focuses on a single reactor type, based on an understanding of the design requirements, and an engineering approach to meeting those requirements derived from open literature, patents, and engineering analysis. Once a cost-representative design is established, the methods for manufacturing the reactor and auxiliary components will be developed in detail to establish the basis for a manufacturing cost estimate. Proposed projects should define the current state-of-the-art in key areas, develop and refine system configurations and designs, provide guidance on R&D gaps, and provide results that help direct future R&D priorities in the implementation of nuclear technologies. The cost of the reference design will be based on thorough understanding of manufacturing processes likely to be used in various production rates. Manufacturing cost will include, but is not limited to: Equipment costs, Labor, Materials, and Energy.

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Reactor Installation Costs—Proposed projects will develop a reference cost-representative plan for the on-site construction and installation of advanced reactor technologies with connections necessary for industrial applications. It is expected that proposed projects will develop a detailed reference design that focuses on an industrial process heat application and installation based on development of requirement definitions addressing anticipated safety, physical security, thermal and electrical demands, and operational and regulatory needs. Once the reference design is established, the methods for construction and installation will be developed in detail to establish the cost to install an integrated nuclear system for a chosen application. The cost of the reference design will be based on thorough understanding the installation process and parameters (e.g., to determine excavation time, equipment, labor, energy) through the use of references, experience, and engineering judgement justifying the underlying assumptions made. Cost of construction and installation of the coupled system will include but is not limited to: site specific architecture/engineering, equipment costs, labor, materials, fuel, licensing, management, construction bonds/insurance, and financing.

Questions – Contact: Jason Marcinkoski, Jason.Marcinkoski@nuclear.energy.gov

q. Nuclear Heat for Polymers, Plastics, and Cellulose Waste Decomposition and Recovery

Applications are sought for novel technology designs that use advanced nuclear reactors to reclaim or recycle polymers, plastics, and resins in consumer products, construction materials, and transportation vehicles. These waste streams can provide a “good” source of carbon for synthesis of fuels and chemicals, including production of the original products. Specifically, nuclear reactors can provide the energy to drive depolymerization and decomposition of plastics and polymers and cellulosic materials that are bonded with organic resins. These waste streams do not breakdown easily in landfills, yet they contain energy and carbon that can be recycled into new products.

Numerous thermal-chemical processes have been proposed or developed that can utilize the thermal or electrical energy produced by advanced, high temperature nuclear reactors. These processes include hydrothermal liquefaction, plasma gasification, supercritical-water or supercritical-CO2 oxidation, and ionic solvents. A common component of these technologies is heat, ranging from around 200 C to 800C. Small/modular nuclear reactor technology can readily supply heat within this temperature range; the key is proper design of thermal energy transport systems, direct heat integration with the decomposition reactors, and useful collection and management of byproduct steams.

Proposed projects should define the current state-of-the-art in key areas, develop and refine heat delivery systems for reactors up to 800 C (e.g., steam, supercritical CO2, or strongly ionic liquids). Designs should consider tradeoffs of batch versus continuous-flow decomposition reactors, scalability, management of off-gas vapors, management of metals and ash residuals and avoiding toxic air pollutants. Design of directly heated reactors, feed-stock preheating, and waste heat recovery should be considered to develop an overall efficient process design. Carbon capture and use as a chemical feedstock or for fuels synthesis is required. Heat recovery may be used for hydrogen production, feedstock heat-up or other purposes. Process data used in designs should be from commercially available system, or backed up with original data sources, or tested within the project.

Proposed projects should include a design, process flow analysis, and capital and operating cost analysis. The process should address a broad spectrum of waste feedstocks, which may include recycled plastics, tires, sorted municipal solid wastes, construction debris, or manufacturing facility waste tailings.

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Questions – Contact: Jason Marcinkoski, Jason.Marcinkoski@nuclear.energy.gov

r. Small Modular Reactor (SMR) Capabilities, Components, and Systems

Improvements and advancements are needed to address capabilities, components, and systems that might be deployed in SMR designs. The economics of SMRs depend on fewer and smaller components, smaller site footprints, and reduced operations and maintenance requirements as compared to the existing fleet. Concepts that can potentially improve SMR plant capability and performance while reducing capital, construction, operations, and maintenance costs are sought through this work scope. The proposed technology or capability should demonstrate and support improved functionality and efficiencies in SMR-specific plant operation and maintenance processes. Proposed technology improvements can be applicable to any SMR design types (e.g., light water, liquid metal, gas, and molten salt cooled) and to both electrical or non-electrical uses but should be available on a timeframe to support SMR deployments in the early 2030's and compatible with an SMR design currently under development. A wide range of technology areas may be considered, but the associated improvement(s) should specifically support or enhance the benefits offered by either a specific SMR or SMR type, or by SMRs as a class.

Applications that address the following technology development areas are NOT of interest for this subtopic and will be declined: new small modular reactor design concepts, instrumentation and control capabilities (unless the proposed technology is convincingly unique to SMRs), sensors, remote operations concepts, fuel design & development, and spent fuel storage & handling.

Questions – Contact: Melissa Bates, Melissa.Bates@nuclear.energy.gov

s. Advanced and Small Reactor Physical Security Cost Reduction

Advanced and small nuclear reactors will not be competitive with other electrical generation sources unless they are able to drastically reduce physical protection costs. Both intrinsic and extrinsic design features should be considered that can significantly reduce either the up-front capital costs or the operational costs. Applications are sought for new ideas or revitalization of past work that has evaluated physical security cost reductions, including new physical protection approaches and the use of new technologies. Preparation of commercial modeling and simulation tools used for security performance assessments to evaluate those approaches will help nuclear vendors with licensing efforts. Recognition may also be given to the differences between first of a kind and nth of a kind deployment.

Questions – Contact: Savannah Fitzwater, savannah.fitzwater@nuclear.energy.gov

t. Advanced and Small Reactor Material Control and Accounting Modernization

Material Control and Accounting will be a critical aspect of operations in future advanced and small nuclear reactors, particularly given the variety of future types and forms under consideration. Applications are sought for improved and modernized mass and material tracking software to reduce costs, improve usability, and increase effectiveness associated with mass and material tracking systems to support material control and accountability (MC&A) requirements for future advanced and small nuclear reactors. Additional information on MC&A work already completed through the Office of Nuclear Energy's Advanced Reactor Safeguards Program can be found at energy.sandia.gov/ars.

Questions – Contact: Savannah Fitzwater, savannah.fitzwater@nuclear.energy.gov

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u. Cybersecurity Technologies for Protection of Nuclear Critical Systems

NE is seeking science and engineering solutions to prevent, detect, and mitigate cyber threats to nuclear energy systems with specific emphasis on digital instrumentation, control, and communication systems. Applications of interest will develop technologies and tools that will enable nuclear energy system designers, operators, and researchers to characterize cybersecurity of instrumentation and control (I&C) components and systems specific to the nuclear energy sector and identify and mitigate cybersecurity vulnerabilities in such components and systems. Technologies of most relevance will: 1) identify and model the characteristics of a nuclear power plant I&C system under cyber-attack; 2) identify the cyber risk impacts of upgrades and maintenance on such systems; and/or 3) facilitate the secure design of future control systems for the existing fleet and advanced reactors.

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

- Develop and demonstrate technologies that enable cyber secure digital I&C system architectures for use in nuclear facilities across a broad range of current reactors and future reactors, including small modular reactors and microreactors.
- Prevent, detect, and respond to cyber-attacks in complex and interdependent I&C systems relevant to nuclear facilities. Of particular interest are methods and tools that address supply chain vulnerabilities, common cause and common access cyber-attacks, and response and recovery to cyber-attack.
- Develop and demonstrate cyber secure wireless technology architectures that enable the use of advanced sensors, actuators, controllers, etc. – architectures that are resilient to cyber-attacks, jamming, and other man-made failure mechanisms.

Applications not of interest include general cybersecurity solutions for information technology, I&C components and systems or wireless architectures, not specific to the nuclear power sector.

Questions – Contact: Contact: Savannah Fitzwater, savannah.fitzwater@nuclear.energy.gov

v. Light Water Reactor Central Alarm Station Simulator Based Human Factors Studies

Simulators provide a platform to train and evaluate responses to a variety of scenarios to better prepare for real world responses. The simulators created by Central Alarm System (CAS)/Secondary Alarm System (SAS) vendors provide the opportunity for a new research area in human factors studies. Applications are sought, in possible partnership with a company or university with a strong human factors' component, to integrate CAS/SAS simulators with security modeling visualizations to engage in full-scope human factor studies with the ultimate goal of moving force-on-force exercises to an augmented reality/simulated environment.

Questions – Contact: Savannah Fitzwater, savannah.fitzwater@nuclear.energy.gov

w. Plant Modernization

Improvements and advancements are needed to address nuclear power plant economic viability in current and future energy markets through innovation, efficiency gains, and business model transformation. This includes transformative digital technologies that results in broad innovation and business process improvement in the nuclear light water reactor fleet's operating model. The modernization of plant systems and processes will enable a technology-centric business model platform that supports improved performance at lower cost, contributing to the long-term sustainability of the LWR fleet, which is vital to the nation's energy and environmental security. Technology should demonstrate and support improved functionality and efficiencies in plant operation and maintenance processes. This will include improvements for both core operations and maintenance work activities, as well as support functions, such as security, management,

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administration, procurement, and radiation protection. Effective modernization requires improved process automation, machine intelligence and computer aided decision making.

To achieve this mission in the nuclear power industry, applications are sought in one of the following plant modernization areas:

- Artificial intelligence/machine learning technologies are sought for troubleshooting and diagnosing nuclear plant operational problems to improve the timeliness and effectiveness of response to emergent degraded conditions. These technologies should enable significant savings in engineering and technical support costs while addressing model explainability concerns. These technologies should be able to integrate into plant processes for automated assessment and correction, including corrective action program, risk management, and work management functions. Further, the technologies should enable third party outsourcing of trouble shooting and diagnosis through data sharing and remote collaboration capabilities.
- Digital twin technologies for operating nuclear plants are sought to reduce costs in plant monitoring and performance deviation detection. These technologies are intended to enhance operational monitoring by detecting anomalies much lower than instrument setpoints, validating them as real plant phenomena verses sensor malfunctions, determining the deviation trend rate, and identifying the degraded component. The technologies will differentiate cascade effects in connected plant systems from the system with the degraded component. The logic of the digital twin will be transparent and immediately available for rapid verification by plant operators and support staff.
- Self-diagnosis and health monitoring technologies for nuclear plant components are sought for elimination of plant surveillances and other forms of periodic testing, enabling exclusive use of condition-based monitoring for applicable classes of plant components. For these components, all credible failure modes will be addressed, with condition status transmitted on a user-specified frequency. The condition information will support real-time risk monitoring and operational determination. These technologies should be able to integrate into plant processes for automated assessment and correction, including **corrective action program, risk management, and work management functions.**

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

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

NDE techniques for in-situ monitoring of cable insulation are an important component of aging management and sustainable operation of the US nuclear power plant fleet. This call seeks proposals focused on the development and improvement of online cable monitoring methods for aging management, reduced cost, and/or improved reliability.

Several methods exist for determining the condition of installed cables of importance in an operating nuclear power plant, both at accessible locations along the length of the cable and of bulk cable health from the terminal ends of cables. Most cable analysis methods, however, are applied when the cables are not energized and often with cables disconnected from their circuits. The ability to monitor cable condition on-line (continuously during operation) or at least without disconnecting or de-energizing the cables could greatly reduce the time and expense associated with cable monitoring. Utilization of such methods may not only reduce cable aging management costs but could increase operational safety and maintenance efficiency through enabling a larger fraction of plant cables to be assessed simultaneously or per outage.

Examples of possible methods include:

- fiber optics for distributed temperature sensing of component local environments;
- on-line spread spectrum time domain reflectometry for circuit health monitoring;

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- on-line FDR (frequency domain reflectometry) or JTFDR (joint time-frequency domain reflectometry); and
- on-line partial discharge testing for low/medium voltage cables.

Questions – Contact: Sue Lesica, sue.lesica@nuclear.energy.gov

y. Materials Protection Accounting and Control for Domestic Fuel Cycles

The Materials Protection, Accounting, and Control Technologies (MPACT) program supports the U.S. advanced nuclear fuel cycles technology developers to effectively and economically address nuclear materials control and accounting (MC&A) requirements. MPACT is seeking grant applications that develop MC&A technologies with application to the front and back-ends of the nuclear fuel cycle. Examples include technologies that can quantitatively or qualitatively measure Special Nuclear Material (SNM) during fuel fabrication, reprocessing, storage, and in waste forms. Applications for both discrete and continuous measurement capabilities are sought.

Grant applications that address border security, nuclear forensics, nuclear medicine, personnel dose monitoring, nuclear weapons related R&D, or remote monitoring are not sought.

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

z. Innovative Fuel Cladding Materials and Core Materials

Cladding is a fundamental component of the fuel elements for fission reactors. It plays a critical role in maintaining the structural integrity and safety of the nuclear fuel during rector operation, being the first barrier against release of actinides and fission products. The requirements for fuel cladding materials are as follows: low thermal neutron absorption, adequate mechanical strength, radiation tolerance, compatibility with fuel, corrosion resistance in coolant. Applications are sought to support longer-term innovative nuclear cladding materials discovery and development for fuel cycle applications. Specific interests include: new composite and novel metallic alloy designs, test and characterization capabilities, investigation of material performance under extreme conditions (e.g., fuel element-to-cladding and cladding-to-coolant interactions, high temperatures, dose/dose rate, and corrosive chemical environments), material fabrication and manufacturing technologies. Surface modifications of advanced cladding is also a potential option for enhancing their performance against operational life-limiting phenomena, which could include, but are not limited to, surface modifications through coating depositions or direct surface alterations, as well as advancements in methods for surface modification testing and characterization.

Grant applications must recognize the technical challenges for fuel cladding materials to be overcome and propose activities that will prove feasibility of their concept in comparison to existing cladding concepts.

Questions – Contact: Ming Tang, ming.tang@nuclear.energy.gov

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

Improvements and advances are wanted for the fabrication, characterization, and examination of nuclear reactor fuel. Advanced technologies are sought for light water reactor fuels and for Advanced Reactor fuels for sodium cooled fast reactors.

- Provide new innovative accident tolerant LWR fuel cladding/assembly concepts that have the potential to support achieving very-high fuel burnups (viz. greater than 100,000 MWD/MTU peak pin average burnup).

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Improvements to LWR fuel and cladding may include but not be limited to fuel constituents or fabrication techniques to improve the overall performance or characterization techniques to improve understanding of performance of the nuclear fuel system. Cooperation is strongly encouraged with a national lab or other entity with fuel fabrication capabilities, as production of a prototypic samples for irradiation would be required for any follow-on phase.

- Develop and/or demonstrate improved fabrication methods for sodium fast reactor fuels and cladding materials, especially for uranium and plutonium based metallic fuels. Manufacturing features of interest include methods to eliminate sodium bonding, produce advanced cladding compositions, methods to apply liners, and fuel slug production processes taking into account retention of volatile constituents associated with reuse as well as special additives or "getters."
- Develop improved fabrication techniques or characterization techniques for silicon carbide accident tolerant LWR fuel cladding and fuel structures to improve the overall fuel performance. Cooperation is encouraged with a national lab or other companies with fuel fabrication capabilities, since the production of a prototypic sample for irradiation would be required for any follow-on phase.

Grant applications may use non-fueled surrogate materials to simulate uranium, plutonium, and minor actinide bearing fuel pellets.

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

bb. Other

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

Questions – Contact: JoAnne Hanners, JoAnne.Hanners@nuclear.energy.gov

cc. Real-Time In Situ Simultaneous Measurement of Density and Viscosity for High-Temperature Molten Salts

High-temperature molten chlorides and molten fluorides are used as a liquid fuel medium and as a heat transfer fluid in several advanced reactor systems as well as heat storage and heat transfer fluids for concentrated solar power. These low-viscosity molten salts typically have a viscosity < 10 cP (< 0.01 Pa·s) depending on temperature and composition. Because the operation of these molten salt systems typically involves pumping molten salts through heat exchangers, real-time in-line or at-line device for measurement of density and viscosity of molten chloride and molten fluoride salts will be need to ensure that the density a and viscosity of the molten salt remains within design specifications. For reactor applications the devices must be able to operate at temperatures up to 800°C and not be affected by ionizing radiation.

Questions – Contact: James Willit, james.willit@nuclear.energy.gov

C58-30. ADVANCED TECHNOLOGIES FOR NUCLEAR WASTE

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

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

Grant applications are sought only in the following subtopics:

a. Spent Nuclear Fuel Rail Transport Risk of Derailment and Release

The primary mode of DOE transport for moving SNF from nuclear power plants to federal storage facilities is expected to be by freight rail. Recent derailment events involving hazardous materials in the U.S. have generated media attention and concern from members of the public, legislators, and others that derailment of trains transporting SNF could result in serious radioactive contamination. While transportation of SNF in the U.S. over the past 70 years has a robust safety record (see *A Historical Review of the Safe Transport of Spent Nuclear Fuel)*, the general public is largely unaware that this material is currently moved, or its safety record.

The DOE Office of Integrated Waste Management (IWM) will need to gain public trust and confidence in the safety of SNF transport to successfully operate storage and disposal facilities. To address questions and concerns about the risks of SNF transportation by rail, it could be useful to produce simulation-based derailment analysis, visuals, and probabilities of release from SNF Type B packages certified by the U.S. NRC (10 Code of Federal Regulations (CFR) Part 71) and transported by freight railcars designed to the Association of American Railroads Standard S-2043, *Performance Specification for Trains Used to Carry High-Level Radioactive Material*, such as the DOE's Atlas 12-axle cask-carrying railcar, DOE's Fortis 8-axle cask-carrying railcar, or other comparable railcar designs. Innovative approaches to computationally and visually represent risks and outcomes of SNF train derailment and release, including visual simulation of possible derailment events, likely impacts to Type B packages, and probability of radioactive release and/or contamination that are technically sound yet suitable for broad public communication are sought.

Questions – Contact: Tran Le, tran.le@nuclear.energy.gov

b. Triple Purpose Canisters for TRISO-based SNF

The DOE IWM is interested in exploring the feasibility of using triple purpose canisters (for storage, transportation, and disposal) for the spent nuclear fuel (SNF) that would result from the operation of advanced reactors, including micro-reactors, designed to use TRi-structural ISOtropic (TRISO) fuel fabricated in spherical pebble form. After permanent discharge from a reactor, pebble-based TRISO SNF would need to be placed in canisters for temporary storage at the reactor site prior to subsequent transportation off site to either consolidated storage or permanent disposal facilities.

This Phase I work effort would explore the feasibility of innovative concepts for a triple-purpose canister for pebble-based TRISO SNF. The goal would be to have a triple-purpose canister which could be used in a set of SNF cask/packaging systems designed to 1) support extended storage at a reactor site or a consolidated interim storage facility (CISF); 2) transportation to a CISF and/or permanent disposal facility; and 3) disposal of the canisters in a wide range of geologies conducive for deep mined SNF repositories. The triple-purpose canister system concept may be developed to contain smaller disposable canisters within a larger canister or carrier to promote efficiencies by enabling multiple smaller canisters to be collectively handled, stored, and transported prior to being separated, if necessary, to promote disposal in certain types of geologies. In addition, the triple-purpose canister concept, when used as part of a transport or storage system, will need to be developed to satisfy regulatory requirements contained in the U.S. CFR such as applicable portions of 10

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CFR Part 71, and 10 CFR Part 72, respectively. Design-basis assumptions for facilitating disposal should be identified as part of the triple-purpose canister concept development work.

Questions – Contact: Tran Le, tran.le@nuclear.energy.gov

c. Storage & Transportation R&D

Spent nuclear fuel (SNF) will continue to be stored, typically in dry cask storage systems, until a determination on final disposition is made. Over 90% of dry cask storage systems in the U.S. are welded dry storage canisters (DSC), typically on the order of 5/8-inch thick (Type 304 or 316) stainless steel, emplaced in either concrete or metal overpacks. The U.S. NRC has identified key safety functional areas for storage, including retrievability, thermal performance, confinement, radiation protection, and subcriticality. It is important to demonstrate that these safety functions are met during extended storage and transportation.

Accordingly, the Storage and Transportation division is tasked with developing the technical basis to demonstrate spent fuel integrity for extended storage periods, to ensure fuel retrievability and transportation after extended storage, and to transport high burnup fuel. The areas of highest priority for the mission are described in the following document: Teague et al. 2019, 'Gap Analysis to Guide DOE R&D in Supporting Extended Storage and Transportation of Spent Nuclear Fuel: An FY2019 Assessment', SAND2019- 15479R, which can be found at https://www.osti.gov/servlets/purl/1592862. Applications are sought for developing novel technologies that support our endeavors in the areas described therein, including i) Chlorine Induced Stress Corrosion Cracking in the Canister Wall, ii) Canister Internal Environment Monitoring, iii) Fuel Cladding Degradation, iv) Stresses and Strains on Fuel Bundle Components due to Transportation or Seismic Loads, or v) other areas.

Questions – Contact: John Orchard, John.Orchard@nuclear.energy.gov

d. Disposal Research

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

Mined geologic repository projects and ongoing generic disposal system investigations generate business and R&D opportunities that focus on current technologies. DOE invites applications:

- Involving novel material development, testing methods, and modeling concept and capability enhancements that support the program efforts to design, develop, and characterize the barrier systems and performance (i.e., to assess the safety of a nuclear waste repository).

- Addressing applications of state-of-the-art uncertainty quantification and sensitivity analysis approaches to coupled-process modeling and performance assessment which contribute to a better assurance of barrier system performance and the optimization of repository performance.

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- Reducing uncertainties in data and in models currently used in geologic repository performance assessment programs.

Research applications are sought to support the development of materials, modeling tools, and data relevant to permanent disposal of spent nuclear fuel and high-level radioactive waste for a variety of generic mined disposal concepts in clay/shale, salt, and crystalline rock. Key research contributions for the disposal portion of this activity may include one or more of the following:

- Improved understanding of waste package failure modes and material degradation processes (i.e., corrosion) for heat generating waste containers/packages considering direct interactions with canister and buffer materials in a repository environment leading to the development of improved models (including uncertainties) to represent the waste container/package long term performance.

- New concepts or approaches for alleviating potential post-closure criticality concerns related to the disposal of high-capacity waste packages. Development of models and experimental approaches for including burn-up credit in the assessment of the potential for criticality assessment for spent nuclear fuel permanently disposed in dual-purpose canisters that are designed and licensed for storage and transportation only.

- Development of pertinent data and relevant understanding of aqueous speciation, multiphase barrier interactions, and surface sorption at elevated temperatures and geochemical conditions (e.g., high ionic strength) relevant to deep geologic disposal environments.

- Identification and assessment of innovative and novel buffer materials, and new methods and tools for multi- scale integration of relevant repository characterization data (including hydrological, thermal, transport, mechanical, and chemical properties).

- Design of new approaches for imaging and characterization of low permeability materials, state-of-the-art tools and methods for passive and active characterization and monitoring of engineered/natural system component properties and failure modes and their capability to isolate and contain waste.

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

e. SUBTOPIC REMOVED

Applications will not be accepted for this subtopic.

f. Krypton-Specific Capture Technologies

Proposals are sought for noble gas capture technologies that are targeted to capture krypton selectively over xenon at near room temperature as opposed to cryogenic distillation. Advanced functional materials composed of metal organic frameworks, zeolites, covalent organic frameworks, porous organic polymers with improved krypton capacity, permeance and selectivity over Xe will be of interest. Further, multi-purpose sorbent that includes combination of sorbents to capture more than one volatile radionuclide (^{129}I, ^{85}Kr, ^{14}C, ^{3}H) is also of interest. The goal is to reduce the off-gas system footprint, column size and cost with subsequent disposal approaches to sequester radio-krypton.

Questions – Contact: Kimberly Gray, Kimberly.Gray@nuclear.energy.gov

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g. Multi-Radionuclide Sorbents and Waste Forms

Proposals are sought for sorbents that have the ability to simultaneously capture multiple radionuclides from complex reprocessing off-gas streams. A clear path for immobilization into a durable waste form should be included in this proposal. The ultimate goal is to reduce the size, complexity, and cost of off-gas control for aqueous reprocessing of spent nuclear fuel and to fulfill the highly demanding requirements for safe disposal over a long time period.

Questions – Contact: Kimberly Gray, Kimberly.Gray@nuclear.energy.gov