U.S. Department of ENERGY | Office of Science

U.S. Department of Energy

Small Business Innovation Research (SBIR) and

Small Business Technology Transfer (STTR) Program

Topics

FY 2025

Phase I

Release 2

November 12, 2024

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

The following topics will be providing responsive LOI feedback: C60-01, 02, 03, 04, 09, 10, 11, 12, 15, 16.

Schedule

Event	Dates
Topics Released:	Tuesday, November 12, 2024
Funding Opportunity Announcement Issued:	Monday, December 16, 2024
Letter of Intent Due Date:	Tuesday, January 14, 2025 5:00pm ET
Application Due Date:	Wednesday, February 26, 2025 11:59pm ET
Award Notification Date:	Tuesday, May 27, 2025*
Start of Grant Budget Period:	Tuesday, July 8, 2025

*** Date Subject to Change**

Table of Changes

Version	Date	Change
Ver. 1	November 12, 2024	Original
Ver. 2	November 13, 2024	• Removal of duplicative subtopic C60-29p (Advanced and Small Reactor Material Control and Accounting Modernization) • Removal of duplicative subtopic C60-29s (Light Water Reactor Central Alarm Station Simulator Based Human Factors Studies)
Ver. 3	November 20, 2024	• Updated Table of Contents to show topic C60-20g (Other)
Ver. 4	November 27, 2024	• Updated topic C60-29gg from “Production of Zr metal by direct electroreduction of ZZrCl4 in molten salt” to “Production of Zr metal by direct electroreduction of ZrCl4 in molten salt”
Ver. 5	December 4, 2024	• Updated the INTRODUCTION TO DOE SBIR/STTR TOPICS section to reflect Phase I Release 2 information
Ver. 6	December 16, 2024	• Updated page 69 to remove “**Reference source not found”** error • Updated bullet points on topic C60-11a (pg. 89)
Ver. 7	January 2, 2025	• Updated Letter of Intent Due Date to Tuesday, January 14, 2025, 5:00pm ET
Ver. 8	January 14, 2025	• Updated cover page to add information about responsive LOI feedback.

INTRODUCTION TO DOE SBIR/STTR TOPICS

This SBIR/STTR topics document is issued in advance of the FY 2025 DOE SBIR/STTR Phase I Release 2 Funding Opportunity Announcement scheduled to be issued on Monday, December 16, 2024. 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:
https://pamsexternalhelp.science.energy.gov/pages/viewpage.action?pageId=103186436.
Please check out the tutorials--a series of short videos designed to get you up to speed quickly.

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 technical and business assistance (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 DOE's Office of Energy Efficiency and Renewable Energy's (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.

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.

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 CESER that works to develop innovative technologies to aid power systems in addressing these threats.

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 security 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.

C60-01. MALICIOUS EVENT DETECTION, DIAGNOSIS, AND RISK MITIGATION

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

This topic will be providing feedback to responsive Letters of Intent.

Research in energy security is focused on tools and technologies that aid in strengthening the security and resilience of the energy sector. This research topic requests applications to develop proofs of concept for unique and innovative solutions that address a need in the detection, diagnosis, and risk mitigation of malicious attacks. 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 on this topic <u>must</u>:

- 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.

- Justify the compatibility of solutions intended for onsite installation 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.

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

All applications to this topic should:

- Prioritize risk reduction 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 subtopics:

a. AI for Malicious Event Detection & Diagnosis in the Energy Sector (IIJA)

As the energy sector continues to expand and diversify with electrical vehicles, increased power needs to meet computational demands, and distributed energy resources, it will increasingly rely on AI for the necessary agility and problem-solving power required to keep the sector safe, resilient, and efficient. In recent years, AI has seen advancements that bring extraordinary promise meet the power generations requirements of an increasingly decentralized sector as well as the security challenges that continue to evolve over time, including cybersecurity.

Among the most important applications of AI in critical energy infrastructure is its potential use in improving security, reliability, and resiliency. Anomalous and malicious event detection & diagnosis are especially promising areas of AI with the potential to contribute meaningfully to these goals. By detecting and understanding attacks as they occur, even novel, never-before-seen attacks, critical energy systems can be better protected from hostile adversaries. This includes not only mitigating damages from ongoing attacks, but also establishing preventative measures for future attacks that may occur.

The proposed solution should cover the use of AI to detect, diagnose, and understand malicious events when the system is in a state that is a deviation from normal operations. Malicious attacks can be either physical or cyber in nature. Unlike natural disasters and other unintentional hazards, malicious events are not probabilistic in nature, but are instead driven by intelligent humans with objectives. Because of this, even greater novelty in malicious events than in non-malicious anomalous events can be expected.

Relevant AI Types that should be used:

- Supervised Learning: Using historical data of prior or well-known attacks, this can enable improved ability to identify patterns from common vulnerability exploitations or attack signatures from known adversaries. Note that a supervised approach cannot reliably detect novel attacks with previously unseen signatures.
- Unsupervised Learning: By not relying on labels of historical or known attack types, unsupervised learning can enable the identification of new patterns for novel attacks from adversaries, which helps to inform operator response.

Questions – Contact: Jodi Kouts, jodi.kouts@hq.doe.gov

References:

1. The White House, 2023, Executive Order on the Safe, Secure and Trustworthy Development and Use of Artificial Intelligence, Executive Order Number 14110, https://www.whitehouse.gov/briefing-room/presidential-actions/2023/10/30/executive-order-on-the-safe-secure-and-trustworthy-development-and-use-of-artificial-intelligence/(October 28, 2024)
2. U.S. Department of Energy, Office of Cybersecurity, Energy Security, and Emergency Response, 2024, Summary Report: Potential Benefits and Risks of Artificial Intelligence for Critical Energy Infrastructure, https://www.energy.gov/sites/default/files/2024-04/DOE%20CESER_EO14110-AI%20Report%20Summary_4-26-24.pdf (October 28, 2024)
3. U.S. Department of Energy, 2024, AI for Energy: Opportunities for a Modern Grid and Clean Energy Economy, https://www.energy.gov/sites/default/files/2024-04/AI%20EO%20Report%20Section%205.2g%28i%29_043024.pdf (October 28, 2024)

b. Distribution Substation Ballistic Risk Mitigation (IIJA)

Our electrical substations are being assaulted by ballistic threats from a variety of actors and weapon types. Many of these substations have only chain link site fences and do not have many cameras or security personnel watching them. The country has an enduring need to deter these attacks and reduce the effectiveness of any ballistic assaults on our important electrical infrastructure. Key security improvement adoption issues include the cost of adoption compared with the potential component economic loss; undesirable site security or operational side effects from security adoptions; ineffectiveness of commercial solutions in the high voltage substation environment; limited utility personnel resources to monitor the infrastructure; and the need for durable equipment that works continuously, for many years, at all times of day and night, hardened against an outdoors, exposed, harsh, all weather conditions environment without frequent repair or replacement.

This solicitation focuses on demonstration of new mitigation technologies that visibly deter attacks and cause ballistic attacks to be less effective. Solutions need to take into consideration the needs of electrical substation equipment to have healthy access to cooling air from the environment; the needs of owner/operators and law enforcement to maintain robust situational awareness of substations when different types of criminal activity is transpiring, both for criminal trespassing on-site and assaults on infrastructure emanating from offsite; and the significant electromagnetic compatibility and interference environment that a substation environment presents with voltages typically over 10 kilovolts (kV) and potentially up to 69 kV. Proposed solutions can include but are not limited to improved camera solutions for law enforcement forensics support, improvements which significantly increase the number of cameras that can be monitored per security person; technology improvements in electrical utility to law enforcement security information sharing for ongoing events; small volume component ballistic protections that do not cause equipment overheating, site fence-line improvements that reduce targeting or other ballistic effectiveness; aesthetic improvements to help blend substations into their environments to reduce attack frequency.

The proposed solution must be applicable for a commercial application related to transmission or distribution of electrical energy. Dual use applications are ok for the proposed commercial solution to also be used for other federal/military applications. Solutions proposed for end-use applications such as protection of key electricity loads or distributed energy generation will be considered non-responsive to the solicitation. Additionally, the proposed solution must clearly indicate the improvement with respect to commercially available solutions from an improved effect at a similar price or a maintained performance with significant cost improvements in the commercialization plan.

Questions – Contact: Joseph Blankenburg, joseph.blankenburg@hq.doe.gov

References:

1. North American Electric Reliability Corporation, 2022, Critical Infrastructure Protection Standard CIP-014-3, Physical Security, https://www.nerc.com/pa/Stand/Reliability%20Standards/CIP-014-3.pdf (October 28, 2024)

2. U.S. Federal Energy Regulatory Commission, 2022, Docket No. RD23-3-000, Order Directing Report, E-27 RD23-2-000 | Federal Energy Regulatory Commission(October 28, 2024)
3. ABB Inc, 2015, "Five steps to substation physical security and resiliency," ABB 5 Steps to Substation Physical Security.pdf (October 28, 2024)
4. Salahieh, N., Miller, J., and Yan, H., 2022, "As North Carolinians regain power, investigators probe terrorism and threats against power substations across the US. One expert explains what needs to be done", CNN, https://www.cnn.com/2022/12/08/us/power-outage-moore-county-investigation-thursday/index.html (October 28, 2024)
5. Johnson, K., 2023, "Planning and protection approach to substation physical security", energycentral, Planning and Protection Approach to Substation Physical Security | POWER Engineers (October 28, 2024)Williams, E., 2023, "The ongoing battle to protect critical substation infrastructure" T&DWorld, The Ongoing Battle to Protect Critical Substation Infrastructure | T&D World (October 28, 2024)

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 2025 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.

C60-02. ADVANCED MATERIALS AND MANUFACTURING 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 Materials and Manufacturing Technologies Office (AMMTO) provides planning, management, and direction necessary for a balanced program of research, development, technology demonstration, and workforce development to drive advancements in next-generation materials and manufacturing technologies. Through accelerating the adoption of these innovative technologies, AMMTO aspires to improve quality of life, increase U.S. industrial competitiveness, and realize a clean, decarbonized economy. AMMTO's mission aligns directly with the national strategic plan that aims to realize a vision of U.S. global leadership in advanced manufacturing to grow the economy, create high-quality jobs, enhance environmental sustainability, address climate change, strengthen supply chains, and ensure national security. AMMTO comprises three programs: Next Generation Materials and Processes (NGMP), Energy Technology Manufacturing and Workforce (ETMW), and Secure and Sustainable Materials (SSM). AMMTO's staff apply their expertise and leadership in smart manufacturing, artificial intelligence/machine learning (AI/ML), manufacturing platforms, critical materials, and circular economy to the development of these subtopics.

All applications to this topic must:

- Clearly indicate the subtopic of interest; for subtopic c, please also indicate the area of interest (AOI).
- Outline the technical approach.
- 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 materials and manufacturing RD&D metrics (including energy-related manufacturing metrics 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 and specific subtopic—related 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; and
- For Phase II only, include a Techno Economic Analysis (TEA) linked with the commercialization plan.

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

AMMTO also is accepting proposals for a joint AMMTO- Bioenergy Technologies Office (BETO) proposals under Topic C60-03.

This topic will be providing feedback to responsive Letters of Intent.

Applications must be responsive to the following subtopics:

a. Digital Twin Technology for Quality Assurance of Clean Energy Products

A manufacturing digital twin (DT) is a virtual representation of real-world manufacturing entities and processes, synchronized at specified frequency and fidelity of the system's behavior in its operating environment [1]. This virtual system abstraction understands the past, provides situational awareness of the present, and anticipates the future, enabling rapid, effective, and proactive decision-making. Deployment of manufacturing DTs can be transformative in enabling digital intelligence for clean energy production [2]. Intelligence in manufacturing translates to faster and timely decision making through advanced knowledge-driven frameworks that include artificial intelligence (AI), machine learning (ML), along with semantic and cognitive capabilities.

The objective is to develop a Quality Assurance (QA) framework for clean energy manufacturing using DT (including, but not limited to, battery manufacturing, wind blade manufacturing, or large metallic component manufacturing for clean energy applications). Take battery manufacturing as an example, there are many quality issues across the entire battery production process – from mixing, coating, drying, solvent recovery, stacking, vacuum curing, slitting, calendaring, welding, enclosing, formation, and aging. The use of data from the production process to predict and control the quality across the entire production process by combining both physics-based and data-driven models will significantly improve the productivity, cost, and efficiency.

The digital transformation of clean energy manufacturing is still in its early stages. There are many reasons for this: 1) a lack of complete understanding of the quality and variability across the production process, 2) a lack of a clear model of cause and effect of process and production parameters on quality, and 3) digitalization opportunities and challenges of production processes – what parameters need to be measured and controlled, how to measure them using metrology equipment and sensors, data pre- and post-processing for data analytics, and software and hardware for a data acquisition system (DAQ).

The proposer should develop a complete analysis of quality and variability issues across the entire production process for selected clean energy application. The proposer should look into the requirements for DT for clean energy manufacturing across all stages of the selected production process – product twin, process twin, equipment twin. The proposer should also develop a small lab-level prototype of a DT (at any stage of the production process), based on the fit for purpose and requirements. Based on the success of Phase I, the project should include supply chain DT in Phase II. In addition to this, the project should document digitalization opportunities and challenges. DT for manufacturing QA could also include cost estimation using tools such as BatPaC for battery manufacturing [3].

The results and the analysis will significantly help manufacturers to improve overall quality and production process for clean energy applications. If successful, this effort will provide a vehicle to encourage small and medium sized enterprises (SMEs) to provide technical solutions to manufactures to achieve higher levels of performance though smart manufacturing practices, DTs, and digital transformation of their manufacturing.

Phase I Metrics of Success (Note: the reports and inventory could be combined into one report)

- A report on the complete analysis of quality issues across the entire production process for the selected clean energy application
- A report on the requirements for DT for manufacturing across all stages of the selected clean energy production process and digitalization opportunities, platform technologies, and challenges
- A comprehensive inventory of required metrology equipment for in-situ measurements, sensor technologies, edge devices, and related digital assets.
- A proof-of-concept of DT at any one stage of the selected clean energy production process
- Test results from the preliminary evaluation and analysis of this prototype

Phase II Metrics of Success —

- Perform Techno Economic Analysis [4] of QA framework to evaluate the economic performance
- Develop a best practice for developing a DT framework for QA for selected clean energy application
- Develop a simple software platform for showcasing the framework
- Feasibility analysis of this QA framework that can be extended to multiple clean energy applications

Questions — Contact: Sudarsan Rachuri, Sudarsan.rachuri@ee.doe.gov

b. Compiler-Based Approaches for Secure by Design for Industrial Control Systems

Smart manufacturing (aka 4th Industrial Revolution) offers vast opportunities for innovation and growth, but it also introduces new risks, particularly in the manufacturing sector. As advanced technologies are integrated into operational technology networks for hyperconnectivity, there is a critical need for sophisticated cybersecurity solutions to protect these systems. However, many manufacturers are still underprepared, lacking the necessary cyber capabilities and monitoring to secure their increasingly connected environments, leaving them vulnerable to emerging threats. Cybersecurity is especially critical for industrial control systems (ICS) and data acquisition systems (DAQ) in the manufacturing industry.

The current ICS and DAQ systems have many cybersecurity weaknesses, increasing risks to manufacturers. The Common Weakness Enumeration (CWE) [1] and Common Vulnerabilities and Exposures (CVE) [2] databases, maintained by MITRE, are crucial for identifying and addressing cybersecurity issues in ICS and DAQ systems. CWE is a comprehensive list of software and hardware weaknesses. These weaknesses are conditions in software, firmware, hardware, or service components that could lead to vulnerabilities under certain circumstances. CWEs help in identifying the root causes of vulnerabilities, which can occur during design, implementation, or other phases of the ICS and DAQ lifecycle. CVE is a list of publicly disclosed cybersecurity vulnerabilities. CVEs help in tracking and managing vulnerabilities across different systems and software. Compiler-based approaches can leverage the CWE and CVE databases and ICS and DAQ system design using Electronic Computer-Aided Design (ECAD) systems, reducing the risk of cyberattacks and ensuring reliability.

The objective is to develop a software system that can capture cyber weaknesses and vulnerabilities of ICS and sensors for DAQ. This software system should help in realizing secure by design [3] and secure by default [4] of design and manufacturing of ICS and DAQ hardware and software systems.

The proposer should develop a complete analysis of CWE and CVE issues for ICS and DAQ. The proposer should design and develop a software system that can capture and visualize cyber weaknesses and vulnerabilities of ICS and DAQ. The software system should include a centralized risk assessment and reporting dashboard for real-time visualization of vulnerabilities and their impact on ICS and DAQ systems. This software could include concepts of compilers for capturing CWEs and use the National Vulnerability Database (NVD) [5] to create reusable templates and libraries that promote "secure by design" and "secure by default" methodologies. The software system should look into various existing languages for both hardware and software for developing ICS and DAQ. The system should be designed for future expansion to include machine to machine communications and edge devices design. Based on the success of Phase I, in Phase II the software system should include a centralized risk assessment and reporting dashboard for real-time visualization of vulnerabilities and their impact on ICS and DAQ.

The compiler-based software system should enhance cybersecurity for ICS, sensors, and DAQ design using ECAD systems. These approaches leverage the compiler to automatically detect and mitigate security vulnerabilities during the design of ICS and DAQ systems. If successful, this effort will provide a vehicle to encourage Small and Medium sized Enterprises (SMEs) to provide technical solutions to the design and development of ICS and DAQ hardware and software system for Original Equipment Manufacturers (OEMs).

Phase I Metrics of Success (Note: all reports could be combined into one report) —
(1) A report on the complete analysis of CWE and CVE issues for ICS and DAQ
(2) A report on the design of the compiler-based software system for capturing CWEs during the design of ICS and DAQ using ECAD system.

A prototype of the software system and test results from (1) and (2)

Phase II Metrics of Success —

(1) Perform Techno Economic Analysis [6] of the software to evaluate the economic performance
(2) Feasibility analysis of this software for other sensors and controllers for manufacturing applications

Questions — Contact: Sudarsan Rachuri, Sudarsan.rachuri@ee.doe.gov

c. Acoustic and Electric Field-Assisted Manufacturing for Better Batteries, Power Electronics, and Microelectronics

Currently, the only high throughput "micro-scale" manufacturing technology is photolithography on thin films for semiconductor chip manufacturing [1]. This particular micro-technology has been enormously successful for the U.S and World economy [2]. AMMTO's recent draft R&D roadmaps [1, 3, 4], however, all suggest that scale up of additional micro-scale manufacturing techniques would be beneficial for the microelectronics, power electronics, and battery manufacturing industries. While magnetic and mechanical (e.g. strain fields) are important too, this subtopic seeks to scale up only two micro-scale field-assisted manufacturing technologies. Specifically, the field-assisted manufacturing technologies of interest for this subtopic are limited to:

- Acoustic [5]
- Electrostatic [6]

The intent of introducing these particular field-assisted technologies is to enable higher throughput and ease of automation, for manufacturing and improved performance of products. In addition, to focus the scale up efforts and build on past AMMTO and other research, the techniques to be developed should first be applied to the millimeter to the micrometer scale wavelength ranges. Therefore, applications of interest include, but are not limited to:

- Battery electrodes
- Power electronics
- Advanced packaging for microelectronics

Another reason to begin scaleup with these applications is that these industries already use acoustic [7, 8] and electric [9] fields for aspects of manufacturing such as cleaning and thermal management. This subtopic, however, seeks proposals that use the full physics of the acoustic and electric fields for patterning applications that enable new manufacturing platform technologies.

Applicable processes to be scaled up include 1) field-assisted augmentations of high-volume manufacturing and 2) field-assisted replacements for low-volume assembly. Specifically, the two areas of interest (AOI) in this subtopic are:

AOI-1) Augmentation: Proposals in AOI-1 also should quantify how the patterning field augments current high volume "micro-scale" manufacturing. For example, in AOI-1) applications, the benefit of the field assistance generally has more to do with ease of automation, lowering costs, and the potential for improving product performance. Responsive proposals must explain the linkage between the ability to precisely model and generate fields and the improved performance of the product manufactured in the application. For example, the current slurry and roll-to-roll processes for manufacturing advanced battery electrodes may be improved by a "micro-scale" acoustic field-assisted approach [4] to precisely control the alignment of particles and enable higher throughput as well as potentially more precise feature detail and control. [10].

AOI-2) Replacement: In AOI-2 the patterning field provides high-throughput alternatives to much slower assembly technologies such as robotic "pick and place." For example, AMMTO microelectronics R&D roadmap recommended designs [1] for much faster heterogeneous assembly of "chiplet" using an electrostatic field-assisted approach that also provides control over material properties that improve thermal and mechanical properties [11]. For AOI-2, throughput must be shown to increase at least an order of magnitude over the course of the R&D project (e.g. from 10 mm/s to 100 mm/s) with the prospects for further order of magnitude improvements. Proposals should discuss potential trade-offs between high-throughput and precision.

All proposals must result in scalable, high-throughput manufacturing for the applications identified. For Phase I, there should be some software and/or field generator developed to enable synthesis and testing of key aspects of the approach.

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

d. Efficient & Responsible Critical Material Refining

Critical materials [1] are the building blocks of many of the technologies that underpin the U.S. energy industrial base. The global shift to clean electricity generation and wide-scale electrification across multiple sectors has led to an unprecedented increase in demand for critical materials because of the essential role they play in these technologies [2]. For many of these critical materials, there are significant gaps in the domestic supply chain – particularly in midstream of refining [3,4]. A key strategy to address these challenges is research and development [5]. This SBIR subtopic provides the opportunity to strengthen the domestic critical materials supply chain by advancing efficient and responsible critical material refining.

Refining of intermediate products often involves high temperature pyrometallurgical methods that release greenhouse gas emissions while hydrometallurgical methods tend to use harsh or corrosive chemicals that present a risk to human and environmental health. For example, molten salt electrolysis — used to reduce neodymium oxide to metal — results in the release of carbon dioxide (CO2) and perfluorocarbon gases [6]. A kilogram (kg) of refined copper produced by smelting generates an estimated 3.3 kg of CO2 – accounting for about 52.8 million metric tons of CO2 in 2020 alone [7]. Reducing energy consumption through investment in advanced processes and technologies can enable domestic manufacturing competitiveness.

This subtopic seeks projects that propose efficient and responsible refining of critical material intermediate products, such as neodymium oxide, that eliminate or minimize the generation of harmful waste, such as greenhouse gas emissions, and improve efficiency of the refining process. Projects that propose the use of less harsh chemicals in processes are also of interest. For the purposes of this subtopic, refining is inclusive of alloying. Improvement in refining may be achieved by automation of processes, reduction of processing temperatures, electrochemical methods, use of green chemistry, process intensification, or other proposed innovations. Proposals must include analysis to demonstrate that the improvements in refining of critical materials represent a minimum improvement of at least 15% in efficiency and/or reduction of harmful waste compared to the state-of-the-art. Proposals must include metric(s) by which to measure the improvement(s) and provide a justification for how the metric(s) targets a significant opportunity to improve efficiency and/or minimize waste.

To be responsive to this subtopic, proposals should evaluate and quantify how the proposed innovation will contribute towards resilient and secure sources of critical materials at a regional or national scale, specify the intended customer base and the specifications required for the refined critical material (e.g., 99.999% purity or 5N), and consider the full lifecycle of materials and processes. Phase I projects must propose a preliminary life cycle assessment (LCA), if one has not already been completed, to compare the new technology to a relevant baseline and demonstrate potential improvements in energy and emissions impacts. Projects that successfully compete for a Phase II award will be required to conduct techno-economic analysis (TEA) and LCA. Recognizing that not all applicants may have prior experience with TEA and LCA, the DOE has developed tools such as the Material Flows through Industry (MFI) tool developed by National Renewable Energy Laboratory. The Critical Materials Innovation Hub (CMI Hub) is a DOE-funded consortium focused on applied research and development to address critical materials. They have developed critical material-specific TEA and LCA open-source tools: Critical Materials Life Cycle Assessment Tool (CMLCAT) [8] and LSM Techno-Economic Analysis [9].

The following critical materials and corresponding end-use technologies and applications are of interest. New methods to refine class 2 nickel into class 1 nickel that present an improvement compared to high-pressure acid leaching for lithium batteries are of interest. The production of cobalt or nickel sulfates or hydroxides for lithium batteries are not of interest.

Application	**Power Generation & Transportation**			**Energy Storage**	**Manufacturing**
Technology	**Motors**	**Superalloys**	**Lightweight Alloys**	**Lithium Batteries**	**Tooling**
Aluminum			X		X
Cerium	X		X		
Cobalt		X			
Copper	X				X
Dysprosium	X				
Neodymium	X				
Nickel		X		X	
Praseodymium	X				
Terbium	X				

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

e. Mechanical Recycling of Textiles

Textile waste is a growing challenge; the EPA estimates that 11.3 million tons of textiles entered landfills in 2018, accounting for 7.7% of all municipal solid waste [1]. There is growing public awareness that trends including “fast fashion” are contributing to rapidly growing waste streams of these hard to recycle materials. Creating a more circular economy for textiles to extend the life of these materials in the economy for longer has the potential for significant impact [2-4]. In addition to expanding repair and reuse, recycling is a promising approach to keep the materials (and their embodied emissions and energy) in circulation after a product has reached its end of life. While promising technologies are being developed for chemical recycling of textiles and fibers, less attention has been given to mechanical recycling approaches. Demonstrating and commercializing new technologies for mechanical recycling of textiles supports EERE’s draft strategic framework on circularity for secure and sustainable products and materials [5].

While not suitable for all end-of-life products, mechanical recycling generally offers the lowest environmental and energy impact of any recycling approach. However, the standard practices for mechanical recycling (e.g. shredding, bleaching, and re-spinning fibers into new yarns) yield shorter fibers, resulting in reduced strength and softness [6]. As a result, most products using mechanically recycled fibers can only incorporate 20-30% recycled fiber to maintain the required material properties [7]. Existing mechanical recycling approaches also work best with mono-material streams. New technologies to mechanically recycle textiles that offer improvements such as retaining longer fiber lengths or avoiding extensive pre-sortation by material have the potential to significantly impact textile circularity.

This topic seeks proposals that aim to mechanically recycle textiles to recover fibers for use in new textile products. For this topic, we define textiles to include clothing, bedding, towels, upholstery fabrics, and carpeting. Technologies should aim to maintain fibers in their highest value application (e.g. avoid “downcycling” to industrial rags or carpet padding when starting with a higher value feedstock such as clothing). Applications must clearly describe what end-of-life textile feedstocks their approach will leverage, and how the required feedstock could be obtained at scale. Applications must also describe how their technology is a significant improvement upon existing textile recycling technologies. Teams that incorporate stakeholders across the required value chain are encouraged.

In addition to the general topic requirements listed before the subtopics, all applications to this subtopic must:

- Include projections for price (e.g. preliminary cost analysis) and performance improvements that are tied to a baseline (i.e. internal baseline and/or published state of the art products or practices).
- Provide a path to scale up in potential Phase II follow on work.
- Be based on sound scientific principles (i.e., abide by the laws of thermodynamics).

Questions — Contact: Allison Robinson Turner, allison.robinsonturner@ee.doe.gov

This topic will be providing feedback to responsive Letters of Intent.

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C60-03. JOINT ADVANCED MATERIALS AND MANUFACTURING TECHNOLOGIES / BIOENERGY TECHNOLOGIES OFFICES TOPIC: PLASTIC CIRCULARITY

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 Materials and Manufacturing Technologies Office (AMMTO) provides planning, management, and direction necessary for a balanced program of research, development, technology demonstration, and workforce development to drive advancements in next-generation materials and manufacturing technologies. Through accelerating the adoption of these innovative technologies, AMMTO aspires to improve quality of life, increase U.S. industrial competitiveness, and realize a clean, decarbonized economy. AMMTO's mission aligns directly with the national strategic plan that aims to realize a vision of U.S. global leadership in advanced manufacturing to grow the economy, create high-quality jobs, enhance environmental sustainability, address climate change, strengthen supply chains, and ensure national security. AMMTO's Secure and Sustainable Materials (SSM) program staff have been collaborating on applying AMMTO's expertise and historical leadership in circular economy to co-development of this topic

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.

All applications to this topic must:

- Clearly indicate the subtopic and area of interest;
- Outline the technical approach;
- 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 materials and manufacturing RD&D metrics (including energy savings where applicable). The program must include quantitative technical milestones, timelines, and expected deliverables that

demonstrate aggressive but achievable progress towards meeting performance parameter targets; Include projections for price (e.g., preliminary cost analysis) and performance improvements that are tied to a baseline (i.e., internal baseline and/or published state of the art products or practices);

- 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; and
- Provide a path to scale up in potential Phase II follow on work — e.g., describe anticipated next steps, scale up, and validation procedures assuming successful completion of Phase I
- For Phase II only, include a Techno Economic Analysis (TEA) linked with the commercialization plan.
- Be based on sound scientific principles (i.e. abides by the law of thermodynamics).

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

AMMTO also is accepting proposals under Topic C60-03.
BETO also is accepting proposals under Topic C60-02.

Applications must be responsive to the following subtopic:

a. Plastic Circularity

The objective of this topic is to advance technologies that will lead to a more circular economy for plastics. This joint topic is a collaboration between DOE's AMMTO and BETO to support the goals of the DOE's Clean Fuels and Products Earth Shot™ [1], the DOE Strategy for Plastics Innovation [2], and EERE's draft strategic framework on circularity for secure and sustainable products and materials [3]. The topic aims to accelerate innovations that will position the US as a global leader in plastics recycling technologies and in the manufacture of new plastics that are recyclable by design. A significant amount of energy is required to produce plastic, particularly when considering the growing volume of plastics that are produced globally. The energy and economic value of these materials is currently wasted as most post-use plastic is discarded in landfills or the environment. Plastics recycling is challenging, in part due to the heterogeneity of modern waste streams. New technologies are needed, both to recycle today's plastics to reduce the demand for primary feedstocks, as well as to design new materials that are recyclable by design [4-6]. The DOE Strategy for Plastics Innovation lays out a vision for the US leading the development and deployment of technologies to address these challenges. The Clean Fuels and Products Shot™ aims to decarbonize the fuel and chemical industries by developing cost-effective technologies to meet the growing demand for materials with sustainable carbon sources. The draft strategic framework on circularity for secure and sustainable products and materials identifies opportunities and challenges to use circularity to decarbonize industry, secure supply chains, benefit communities, and create jobs. All three initiatives can be supported by developing technologies for plastic recycling and by designing more circular plastics.

This topic seeks proposals in two Areas of Interest:

- Area of Interest 1. Seeks proposals for recycling today's plastics in a circular approach, using it as a feedstock to create new plastic or products, rather than for energy or fuels, or
- Area of Interest 2. Seeks proposals for developing new, recyclable by design or biodegradable plastics from sustainable, renewable feedstocks.

This topic builds on previous funding opportunities from AMMTO and BETO including the "Bio-Optimized Technologies to Keep Thermoplastics out of Landfills and the Environment" (BOTTLE) FOA [7] and the "Single Use Plastic Recycling" (SUPR) FOA. [8] Significant progress has been made toward realizing the aims of these FOAs and this topic will build on progress in those projects and related developments in the field.

Rigid plastics and films (e.g. packaging materials, multilayer films, etc.) are of interest; applications should clearly describe what plastic feedstock(s) and product(s) are being targeted by their approach. Textiles and fibers are not of interest for this topic. Applications must clearly describe how their technology will be integrated into the existing plastics manufacturing or recycling industry and display an understanding of the remaining work needed to commercially deploy the proposed technology. Phase I projects must propose a preliminary life cycle assessment (if one has not already been completed) that demonstrates feasibility to reach target emissions and energy reduction when comparing the new technology to a relevant baseline (see tables below). A full lifecycle assessment will be required for Phase II work. Teams that incorporate stakeholders across the full value chain are encouraged.

Area of Interest 1: Recycling Today's Plastics
The application should propose a realistic path to meet all the minimum targets in Table 1 by the time the product is commercially deployed.

Table 1. Recycling technologies for today's plastics

Metric	Unit	Minimum	Stretch Target
Energy savings when compared to production of the same or similar product from virgin material	% energy savings	40%	80%

GHG reduction compared to virgin plastics production	% GHG reduction relative to baseline	50%	80%
Chemically recyclable, as measured by % recovered monomers or intermediate chemicals	% recovered monomers or intermediate chemicals by mass	80%	100%
Economically Incentivized	% cost savings relative to baseline	10%	20%

Area of Interest 2: Development of Recyclable by Design or Biodegradable Plastics
The application should propose a realistic path to meet all the minimum targets in Table 2 by the time the product is commercially deployed. Note that one of the metrics for highly recyclable plastics differs from biodegradable/compostable plastics. Applications must indicate which of the two metrics in Table 2 below that they plan to target.

Table 2: New polymers that are recyclable by design or biodegradable

Metric	**Unit**	**Minimum**	**Stretch Target**
Highly-Recyclable: Recyclable through chemical, biological, or hybrid methods as measured by % recovered monomers	% recovered monomers by mass	50%	100%
Biodegradable/Compostable: Ability to biodegrade in relevant conditions or compost in industrially relevant conditions. Applicants must propose to use ASTM D6400, D5338, D6868 or another relevant standardized test for testing biodegradability/ compostability	Conversion of plastic carbon into CO_2 (or CO_2 and CH_4) as measured by % carbon (applicant must specify the environmental conditions for testing).	Biodegradable: 60% after 180 days. Compostable: 60% after 180 days.	Biodegradable: 90% after 180 days. Compostable: 90% after 180 days.
All Applications: Performance advantage (outperform traditional plastics for a specific application; in this case performance advantage cannot solely be end-of-life properties or bio-based content)	Variable	Meets performance requirements of incumbent material	20% improvement

In addition to the general AMMTO and BETO requirements, all applications to this joint topic:

- For applications that target existing plastic waste (Area of Interest 1), must include a representative, real waste stream as a feedstock;
- For applications that target new plastics (Area of Interest 2), must identify a renewable feedstock and include real, representative feedstock in the project work;
- Must describe the end-of-life fate of the recycled or bioplastic (e.g., recycled or biodegraded) and justify why this is appropriate for the likely use of the material;

This topic will be providing feedback to responsive Letters of Intent.

Questions — Contact: Allison Robinson Turner, allison.robinsonturner@ee.doe.gov from AMMTO and Lisa Guay, lisa.guay@ee.doe.gov from BETO.

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C60-04. 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.

The optimal use of biomass resources is critical to the success of several multi-agency government initiatives such as the Energy Earthshots™ - Clean Fuels and Products Shot Initiative and the Sustainable Aviation Fuel (SAF) Grand Challenge, a government-wide approach to reduce the cost, enhance the sustainability, and expand the production of domestic SAF to meet 100% of the aviation fuel demand by 2050.

Grant applications are sought in the following subtopics:

a. Bioenergy Feedstock Logistics Improvements (EES)

BETO supports small companies prioritizing the commercial mobilization of renewable carbon resources that can replace either petroleum-based or animal-based products. Many incumbent materials and durable goods pose sustainability challenges including the use of hazardous chemicals during manufacturing, reliance on fossil fuel feedstocks, and unsustainable 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 the development and optimization of biomass harvest, collection, storage, handling, transportation, and preprocessing technologies and logistics. Proposals should focus on increasing the overall value of the biomass by maximizing efficiency of the biomass supply chain from on-farm processes through preprocessing to produce conversion-ready feedstocks for production of fuels and products.

Specific logistics improvements of interest include (but are not limited to):

- Processes for scaling or producing bioenergy crop starter materials such as seeds, rhizomes and propagates, including storage, selection and breeding, and rapid propagation techniques. Technologies that could be used to safely scale, derisk, or improve the quality of novel, highly productive and resource efficient bioenergy crop starter materials are of particular interest.

- Technologies, methods, and/or formulations for producing and converting algae biomass or algae biomass-derived materials into fuels
- Development of low-cost algal pond automation tools to be used at commercially-relevant scales, including culture monitoring, media preparation, dilution and filling
- Development of an affordable, representative lab-scale membrane harvesting system to more efficiently harvest algal cultures from research ponds (<1000 L)
- Improvement of planting, harvesting, collection, and on-farm transport equipment for small-scale bioenergy crop production (smaller farms or smaller plots of marginal lands within larger ownerships).
- Development of preprocessing strategies and technologies that reduce overall logistics cost, reduce energy usage, and prepare one or more varieties of feedstocks for conversion
- Transportation logistics and feedstock handling improvements related to a centralized processing facility or collection facility/feedstock blending depot

Topic Requirements:

- The logistical improvements must be applicable to at least one of the following feedstocks:
    - Lignocellulosic biomass (such as corn stover, forestry residues, paper/pulp residues)
    - Purpose-grown energy crops
    - 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
- By the end of Phase 1, the project must have tested actual biomass or waste streams in the logistical improvement being developed.
- As part of the application, applicants should include a preliminary TEA. A preliminary LCA is encouraged, but not required at the time of application. To be eligible for Phase 2, an LCA must show a GHG savings of >70% relative to petroleum incumbents or counterpart molecules.
- Processes must exhibit the potential to be scaled up to pilot- or demonstration-scale.
- Projects must demonstrate procedural justice in technology design and development including sustained, engaged community integration in innovation of new technologies

- Logistics improvements must show favorable life-cycle metrics such as lowered greenhouse gas emissions, water quality improvement, and climate benefits
- Projects must be in line with BETO's mission and goals as outlined in the 2023 Multi-Year Program Plan.

This topic will be providing feedback to responsive Letters of Intent.

Questions – Contact: Elizabeth Burrows, Elizabeth.Burrows@ee.doe.gov and Sara Gonzalez, Sara.Gonzalez@ee.doe.gov

BETO is also contributing to joint topics on Plastic Circularity and Energy Efficient Aqueous Separation Technologies.

C60-05. BUILDING 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

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 Windows1. 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.

a. 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) Low cost krypton extraction and filling, b) Innovative spacer designs that accommodate two center lites with only having two seals in quad pane insulated glazing units, c) thermal frame caps for use with

[1] Pathway to Zero Energy Windows: Advancing Technologies and Market Adoption (nrel.gov)

secondary window/glazing systems and can reduce the thermal loss of vacuum glazings, d) low conductive infill materials, etc

b. Improved Installation of Windows - There is a need to improve the ease of replacing windows that is needed when a “replacement window” (a window that is inserted in the existing frame of a window) is not possible and a “new construction” window is needed. This involves interface with the existing siding. The goal is to reduce labor, cost while improving water and air sealing.
c. DOE also seeks solutions that can improve speed and installation of window replacements that are done in conjunction with residing jobs that incorporate a layer of continuous rigid insulation. Today, approximately 2 million homes are resided each year, presenting an opportune time to improve energy efficiency of the building envelope during a time that the envelope is already deconstructed for the remodel. A significant challenge of adding a continuous layer of insulation while residing is the extra detailing that is introduced at the interface of window penetration through the wall. Continuous insulation is typically added at a depth of 1-2”, which pushes the newly finished cladding plane out the same depth, therefore complicating the sealing, flashing, and aesthetic detailing. DOE is seeking solutions to simplify and speed-up the labor required with replacing windows while adding a layer of 1-2” continuous rigid insulation during residing jobs.

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 building loads while facilitating space and water heating electrification. BTO seeks the development, validation, and commercialization of next generation TES technologies for residential heat pump systems, residential heat pump water heaters, commercial rooftop units, and refrigeration systems. Key drivers in making TES systems economically viable are the costs to integrate thermal storage with equipment. These costs include the integration of thermal storage materials, heat exchangers, valving, packaging, controls, and installation. This TES topic focuses on developing TES systems with low integration costs, improved performance, and ease of installation to accelerate adoption of TES systems in buildings.

- To better facilitate the increased use of thermal storage in residential and commercial space conditioning, water heating, and refrigeration applications, and to lower the installation costs of these equipment-integrated thermal storage systems, work must be done in the following areas:

- Develop TES-heat pump systems with enhanced cold climate and defrost performance, comfort, peak shifting ability, and energy efficiency.
- Develop systems that simplify integration, installation, control, maintenance, and reduce first costs.
- Develop systems for space or weight constrained applications.
- Support market adoption of these thermal storage systems with OEM partnerships as needed.
- Other opportunities for improvement, not identified here.

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

c. Advanced Air Leakage Detection and Air Sealing Technologies

The Department of Energy's Affordable Home Energy Shot seeks to reduce energy costs by 20% for the 50 million households earning less than 80% of the area median income. This topic will enable cost savings and energy efficiency improvements through the development of air leakage detection and sealing technologies for building upgrades. 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. 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 buildings 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.

Key Challenges in the Technology Area:

- Current practices to identify air leakage in buildings can be time-consuming and require specialized equipment run by a trained professional.
- Current practices for effective air sealing often require envelope disassembly and reassembly, which can be disruptive, expensive, and time-consuming for the occupant, even requiring the occupant to leave the premises in some instances.
- Commonly, some of the leakiest parts of a building that need to be sealed are in hard-to-reach areas like attics, walls, finished basements, crawlspaces, and more, which further exacerbates cost and time challenges described above.

Questions – Contact: Kyle Biega, kyle.biega@ee.doe.gov

d. High Performance Insulated Cladding for Residential Field Applied Applications

The Department of Energy's Affordable Home Energy Shot seeks to reduce energy costs by 20% for the 50 million households earning less than 80% of the area median income. This topic will enable cost savings and energy efficiency improvements through the development of non-invasive and low-impact retrofit techniques for building upgrades. Today, approximately 2 million homes are resided each year with minimal insulation such as "fan fold" foam board offering R1 performance. Insulated vinyl siding improves this performance to roughly R2.5-R3 but installed cost tends to have a high price premium and performance falls short of at least R5 continuous insulation that is routinely installed in new construction per building code requirements. BTO seeks innovative solutions that offer at least R5 insulating cladding solutions for one or all of the typical siding products including vinyl, wood, fiber cement, engineered wood, etc. The additional R-value added by the cladding system should be equivalent to adding a layer of continuous insulation of identical R-value, i.e., a cladding system adding R5 should increase the overall wall assembly R-value by R5. The designs should focus on at least R5 performance and be easy to install with consideration of interfaces including fenestration, roof to wall, wall to foundation, and typical construction penetrations. The overall system should ensure that proper moisture control and air sealing can be applied, potentially even as part of the insulated cladding system itself, while ensuring the building will have long term performance without degradation. Long-term predicted performance through modeling programs such as WUFI are highly encouraged. Finally, cladding selection is driven by aesthetic considerations that need to be considered during the development process. The total installed re-cladding system price premium over existing cladding systems should be affordable based on life-cycle-cost basis with preferred simple pay back of less than 15 years when installed on homes in cold climates that have R11 cavity insulation.

Awardees are expected to develop representative proof of concept prototypes at sufficient scale that demonstrate installation details and airtightness and watertightness of the proposed technology. Simulation results that indicate long-term predicted performance of the retrofit solution are highly encouraged.

Parameters	**Minimum Performance**	**Preferred Performance**
Thermal performance	R5 CI	R10 CI
Max combined thickness of insulation and cladding (in)	2 (ideally ≤ 1")	3 (ideally ≤ 2")
Detailing	Uses readily available materials or components that can be easily manufactured to meet quick demand	
Cladding types	Fiber cement, vinyl, wood, engineered wood	

Key Challenges in the Technology Area:

- Current residing practices offer little to no energy efficiency benefits, which poses a missed opportunity to add additional insulation and/or air-sealing, for this commonly executed remodel activity.
- During current practices of adding continuous insulation while residing, an additional rigid foam layer is added between the existing sheathing and new siding. This extra layer requires proper and time-consuming detailing and taping, particularly at interfaces with windows, roofs, and foundations, which requires new skills for the contractor to learn and can increase contractor time on the job. Therefore, proposed solutions to this topic must be able to fold seamlessly with existing workforce skills and practices.

Questions – Contact: Kyle Biega, kyle.biega@ee.doe.gov

e. ResStock Data Analysis Tool for States and Local Governments

ResStock is the best-in-class, DOE funded & NREL developed, building stock energy model for simulating energy use, utility bills, and greenhouse gas emissions in the residential sector of the U.S. ResStock answers two primary questions: (1) How is energy used in the U.S. residential building stock? and (2) What is the impact of energy-saving technologies? This model, and the datasets it produces, are foundational to identifying pathways to affordable and equitable decarbonization of the U.S. residential buildings sector. BTO would like this data to be accessible to more users who don't have resources to fund analysis of large datasets. An online data analysis tool for States & Local Governments, and other local users, can leverage this data for use in equitable policy development.

Key Challenges in the Technology Area:
To facilitate the creation of a data-based policy planning tool for states and local governments, amongst other local users:

- Develop an online tool that graphically illustrates baseline data for energy consumption, thermal component loads, greenhouse gas emissions, and energy use for the existing US residential housing stock
- Enable filtering and display of data by climate type, location, building characteristics, and energy use
- Graphically illustrate decarbonization reduction scenarios data useful for State and local market transformation plans

Questions – Contact: Asa Foss, asa.foss@ee.doe.gov

f. Multifamily Energy Use Data Research

There is little data publicly available of energy use in multifamily buildings that is coupled with the building's characteristics (physical components such as heating / cooling system type, ventilation system type, and water heating system – including central vs in-unit and fuel.) Strategic Analysis just completed a pilot program that emphasizes the lack of data, especially for low-income properties. This data is needed to provide solutions for multifamily properties to meet Building Energy Performance Standards specifically, and more generally to decarbonize low-income and market rate multifamily properties. In addition, BTO is currently working to update the ResStock multifamily building energy modeling. This data is crucial for calibrating the model to create future electrification scenarios.

Key Challenges in the Technology Area:
To facilitate the expansion of publicly available multifamily building energy data:

- Research existing publicly available regional data sources that collect utility bill data and/or building characteristics
- Engage with existing data sources and select at least one to collect comprehensive building characteristics AND utility bill data.
- Evaluate existing data repositories like the LBNL Building performance database for the best central location for the data.
- Develop a method to anonymize and translate data from existing data sources into the central location. Re-engage with stakeholders to coordinate data sharing and facilitate uploading of data from available sources to the central location.

Questions – Contact: Asa Foss, asa.foss@ee.doe.gov

g. NO2 monitors

The oxides of nitrogen are one of EPA's six criteria pollutants governed under the Clean Air Act, due to their known impact on health. Recent research has shown nitrogen dioxide as a primary pollutant of concern within indoor environments as well, particularly in homes and apartments. While there are a variety of monitors/alarms for detecting carbon monoxide in homes available, there are few that detect NO2. To educate and protect home occupants, BTO is interested in consumer grade NO2 monitors with +/-25% expanded uncertainty at 100 ppb NO2. To protect worker health, BTO is also interested in NO2 alarm that can be worn by trades people when they are working in homes/apartments. Either should have a retail price of no more than $100.

Key Challenges in the Technology Area:

To realize BTO's goal on this topic, work must be done in the following areas:

- Develop and bring to market consumer grade NO2 monitors with sensors with +/-25% expanded uncertainty at 100 ppb NO2 with a retail price of $100 or less.
- Create a testing and evaluation system to determine the accuracy of consumer grade NO2 sensors to ensure minimum accuracy parameters are met.
- Other opportunities for improvement, not identified here.

Questions – Contact: Asa Foss, asa.foss@ee.doe.gov

h. Heat pumps for manufactured houses.

Summary of Technology Area:

BTO is supportive of the development of heat pumps for use in manufactured homes. To date, efforts have focused on a single OEM and developer of manufactured housing as a proof-of-concept. BTO would like to expand this to an OEM-agnostic HVAC conversion system for all new manufactured homes. In addition, BTO would seek a ducted heat pump 'add-on' [either underbelly or overhead] for existing manufactured homes.

Key Challenges in the Technology Area:

To better facilitate the use of heat pumps in new and existing manufactured homes, work must be done in the following areas:

- Develop OEM-agnostic HVAC conversion systems to facilitate their use in new and existing manufactured homes
- Creation of heat pump systems that physically fit in the available space and can be integrated seamlessly with the existing duct system.
- Other opportunities for improvement, not identified here.

Questions – Contact: Asa Foss, asa.foss@ee.doe.gov

i. **Easier & More Accurate Manual J Technology**

Summary of Technology Area:

Load calculations determine the heating and cooling design load for a home or apartment. An accurate load calculation allows for the proper sizing and specification of heating and cooling systems, increasing the system's efficiency, performance and durability. However, sizing using home-specific features is not often done due to the time/cost to perform this analysis. ACCA Manual J is a commonly used load sizing methodology. BTO believes there may be alternative options that would require less time or effort to complete while maintaining accuracy thereby increasing the frequency with which load calculations are performed.

Key Challenges in the Technology Area:

To better facilitate the use of load calculations, work must be done to address the following challenges:

- Creation of a load calculation tool that significantly decreases the time and/or effort to complete over standard practice for HVAC technicians working in existing homes, while maintaining the accuracy of the calculation.
- Seamless integration with equipment selection, including considerations such as low-load performance maximization and modulation capacity.
- Convening of stakeholders to drive further industry-wide buy-in and greater understanding of current/potential methodologies.
- Other opportunities for improvement, not identified here.

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

j. **Serviceable Mini-Split/PTHP/PTAC**

Summary of Technology Area:

Hotels, motels, assisted living facilities, dormitories, and other applications requiring individual zone space conditioning commonly use packaged terminal ACs and HPs, representing 0.024 quads/year of primary energy use nationally. In residential buildings, split system ACs and HPs are the most common type of central space conditioning product. Among these products, ductless units are particularly susceptible to accumulation of 1) dirt due to poor air filtration and 2) mold, bacteria, and other biotoxin as the blower operates below dewpoint and collects condensate while cooling. These two factors can yield poor indoor air quality and adverse health effects without regular, time-consuming, labor-intensive, and expensive cleaning.

Key Challenges in the Technology Area:

To mitigate adverse indoor air quality impacts for products including, but not limited to, 1) non-ducted single- or multi-split ACs and HPs and 2) non-ducted split packaged terminal ACs and HPs are used, BTO seeks to:

- Develop and demonstrate AC/HP designs—with comparable or better energy efficiency than currently available models—with lower propensity of contamination even while operating in humid climates, including through heads and coils that can be easily cleaned in less than 15 minutes per head.
- Support market adoption of these designs, with OEM partnerships as needed.
- Other opportunities for improvement, not identified here.

Questions – Contact: Payam Delgoshaei, payam.delgoshaei@ee.doe.gov

k. Highly Efficient Dehumidification

Summary of Technology Area:

As housing becomes more efficient, there is a decrease in the sensible cooling load. However, the latent load does not decrease at the same rate – and in same cases it increases – resulting in higher indoor humidity levels. While properly sized and variable speed air conditioning can help decrease indoor humidity levels versus standard practice, this is still often insufficient to maintain healthy, comfortable indoor humidity levels. Supplemental dehumidification is often done by loud, inefficient room dehumidifiers or through expensive dehumidifiers that are integrated with a ducted air conditioning system. Research has shown that dehumidifying air uses roughly the same amount of energy as cooling the air, and that there is a significant opportunity for efficiency improvements.

Key Challenges in the Technology Area:

To mitigate adverse indoor air quality and comfort impacts for homes with high indoor humidity levels, BTO seeks to:

- Develop and demonstrate highly-efficient dehumidification approaches that can be integrated into a ducted heat pump and/or standalone dehumidifiers that are substantially quieter than the status quo
- Support market adoption of these designs, with OEM partnerships as needed.
- Other opportunities for improvement, not identified here.

Questions – Contact: Payam Delgoshaei, payam.delgoshaei@ee.doe.gov

l. Heat Pump Water Heater (HPWH) Installation Cost Reduction

Summary of Technology Area:

HPWHs are an efficient, electric technology that are a viable option for all Americans. Ensuring easy, affordable access to these units is key, and a large portion of the cost stems from installation costs. Certain installations can be complicated (involving ducting, water heater relocation, etc.) where as others are quite simple (minimal replumbing to fit with a slightly large unit). DOE is interested in novel ideas to minimize the installation costs of HPWHs in either of those categories.

Key Challenges in the Technology Area
To minimize the installation costs of HPWHs, BTO seeks to:

- Contractor tools to assist with ease of installation
- Innovations that minimize the difficulty of emergency replacements with HPWHs, including both hard and soft costs
- Technologies to assist with things such as ducting, re-piping, condensate management, etc.
- Business model innovations to minimize cost increases at each scale of the HPWH supply chain
- Other opportunities not identified here.

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

C60-06. GEOTHERMAL HEATING AND COOLING

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: YES	Accepting STTR Fast-Track Applications: YES

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

The global need for sustainable and energy-efficient heating and cooling solutions is growing rapidly. Geothermal heat pumps (GHPs) offer significant energy savings and environmental benefits by using the stable temperatures beneath the Earth's surface to heat and cool buildings or other spaces. However, current drilling systems for GHPs often require large equipment and significant space, making them less viable for dense, urban, or built environments. This creates a need for innovative, small-footprint drilling systems that are cost-effective, highly efficient, and suitable for constrained spaces.

Opportunities also exist to improve GHP cost effectiveness through advancements in system sizing and design processes. Uncertainties in subsoil properties that drive the sizing calculations for ground heat exchangers create significant project risk, and advancements are needed in methods for site assessment and system sizing. This funding opportunity will support projects to advance the state of the art in all of these areas.

In addition to the broadly applicable technologies mentioned above, this funding opportunity will support development and deployment of geothermal heating and cooling technology specifically designed for the agricultural sector, where there exists a need to improve overall system resilience and where energy is often a major driver of operating cost.

All the following research subtopics involve technological advancements in systems rather than specific components and may require multiple innovations and participants in order to be successful. As such, collaborative proposal submissions are allowed. A collaborative proposal is one where multiple investigators coordinate their applications to team up on a single integrated project. Each institution in such a team must be a small business. Each institution may include one or more academic or lab partners as subcontractors. Each institution must submit an application that contains an identical narrative section and a common statement describing how any intellectual property issues will be addressed by the collaboration. Each application must have an institution specific budget and budget-justification forms, biographical data for the PI and senior personnel involved in the project, and a commercialization plan. The budget proposed for each participating business must separately comply with the ceiling, floor, and other requirements in the Funding Opportunity Announcement. The cover sheet for each submission must clearly show all institutions involved in the collaboration. In addition, please note that each small business participating in the collaboration must submit a Letter of Intent. This opportunity is for ambient temperature geothermal resources only; traditional hydrothermal and enhanced geothermal system (EGS) applications are not of interest.

a. Low-impact drilling systems for GHPs

The purpose of this subtopic is to support the research, development, and demonstration of advanced drilling systems for geothermal heat pumps, with a focus on compact, automated, and robotic technologies. These systems should enable geothermal heat pump installations in built environments near residential, commercial, and industrial buildings or construction sites with limited space for traditional drilling operations. Proposals should target significant cost reductions over current market standards.

This FOA seeks proposals for the development of next-generation drilling systems for geothermal heat pumps, designed for urban and built environments. Specifically, the GTO is looking to advance the state of the art in one or more of the following areas:

Innovative Drilling Technologies:

- Small-footprint drilling systems that can operate in constrained urban and suburban spaces and reduce the risk of damage to existing structures and landscaping.
- Systems that reduce installation time, cost, and site disturbance.
- Novel designs that improve the overall efficiency and reliability of the drilling process.

Robotic and Automated Drilling Systems:

- The use of robotics and automation to reduce costs, improve precision, and enhance safety.
- Systems capable of autonomous operation with minimal human intervention.
- Technologies that can integrate real-time data acquisition for optimal drilling performance and to inform heat exchanger design.

Environmentally Friendly Solutions:

- Drilling systems that minimize environmental disruption, noise, and emissions.
- Technologies that reduce the use of water or other consumable resources and generation of waste during the drilling process.

b. Rapid Site Assessments for Geothermal Heat Pumps

This subtopic seeks to develop advanced tools and technologies for rapid site assessment and screening of locations for geothermal heat pump (GHP) installations. Successful applications will demonstrate clear potential to accelerate geothermal heat pump adoption by addressing current market barriers related to site assessment, heat exchanger sizing, and permitting.
The development of these technologies will significantly reduce the upfront risk, cost and time associated with system design and permitting. These advancements will help expand the adoption of geothermal heat pumps, particularly in underserved areas where the complexity of site assessment has been a barrier to entry.

Projects under this subtopic should aim to:

- Enhance the efficiency, precision and reliability of geotechnical investigations to inform geothermal system design.
- Facilitate the rapid deployment of geothermal heat pumps by providing easy-to-use, integrated assessment tools.

These tools should enable efficient, accurate, and cost-effective characterization of subsoil properties critical to geothermal heat exchange. These kits may include:

Rapid Measurement of Subsoil Properties:

- **Thermal Conductivity**: Tools or instruments capable of quickly measuring the thermal conductivity of subsurface materials at varying depths with high precision.
- **Heat Capacity**: Technologies to assess the heat storage potential of the subsoil, including the ability to measure relevant properties like specific heat and moisture content to estimate thermal diffusivity.
- **Databases:** Large databases of geotagged measurements, observations, reports, and locations of existing subsurface infrastructure to enable the identification of favorable locations, system designs, and policies for broad GHP deployment initiatives

Permitting and Compliance Support:

- **Regulatory Compliance Tools**: Development of tools to streamline the permitting process for geothermal installations by automatically generating site reports or ensuring compliance with local, state, and national regulations.
- **Environmental Study Tools**: Solutions that assess the environmental impacts of geothermal heat pump installations, making it easier to comply with environmental permitting requirements.

Desired Features

- **Speed and Efficiency**: The tools must allow for rapid on-site measurements, reducing the time and cost of the site assessment process.
- **Precision and Accuracy**: High accuracy in determining key subsurface properties, which are critical for the efficient design and performance of geothermal heat exchangers.
- **Ease of Use**: Tools must be easy to use in the field by a wide range of stakeholders, including non-specialists, contractors and installers, local planning authorities, landowners, real estate developers, or others.
- **Data Integration**: Where possible, tools must provide outputs that can be easily integrated into system design software or shared with permitting agencies.
- **Scalability**: Solutions that are applicable to a wide range of environments, from urban to rural settings, are preferred.

c. Geothermal Heating and Cooling for Protected Agriculture

This subtopic aims to develop and demonstrate geothermal heating technologies tailored for protected agriculture environments, including greenhouses, hoop houses, and other controlled-environment agricultural structures. The goal is to create efficient, cost-effective geothermal heating solutions that can support year-round food production, enhance energy efficiency, and reduce reliance on fossil fuels in agricultural heating. GTO is particularly interested in scalable concepts that show promise for broad applicability in a region or climate zone, concepts that reduce water intensity, and concepts that support the development of more resilient, decentralized, and local food systems.

Projects in this subtopic should focus on designing, developing, or demonstrating geothermal heating or cooling systems specifically adapted for the unique needs of protected agriculture spaces. Technologies using heat pumps or direct heat exchange are both of interest, as are technologies using an intermediate fluid or direct air contact. Projects that would implement GHPs outside of the specified agricultural setting are not of interest. The proposed solutions should address one or more of the following areas:

Geothermal Heating and Cooling System Design and Demonstration for Agriculture:

- Development and integration of geothermal heating and cooling solutions optimized for greenhouses, hoop houses, and other similar structures.
- Solutions tailored to the unique heating demands of various crops and climates, ensuring optimal plant growth conditions while minimizing energy use.
- Innovations in seasonal or diurnal geothermal energy storage systems that can store excess heat during warmer periods for use in colder periods.

Integration with Renewable Energy Sources:

- Exploring hybrid systems that combine geothermal heating with other renewable energy sources (e.g., solar, biomass) to further reduce environmental impact and energy costs.
- Systems that can operate off-grid or in conjunction with other sustainable power sources, particularly for rural or remote agricultural operations.

Demonstrating Economic and Environmental Benefits:

- Estimating the cost savings, energy efficiency, and environmental benefits (e.g., reduction in greenhouse gas emissions) of using geothermal heating or cooling for agricultural operations.
- Tools or models for calculating the return on investment (ROI) for agricultural operators adopting geothermal heating or cooling systems, including projections of energy savings and crop yield improvements.

Desired Features:

- **Sustainability**: Systems that significantly reduce or eliminate the need for fossil fuels in protected agriculture heating, contributing to cleaner, greener food production.
- **Reliability**: Geothermal heating solutions that provide consistent and reliable heating to maintain optimal growing conditions throughout the year, especially in colder climates.
- **Cost-Effectiveness**: Technologies that offer a clear financial advantage over traditional heating methods, both in terms of installation costs and long-term operation and maintenance.
- **Adaptability for Small to Large-Scale Operations:** Scalable geothermal solutions that can be applied to both small-scale local farms with an emphasis on affordability and ease of maintenance or large-scale commercial greenhouse operations.
- **Climate Flexibility**: Systems that can adapt to different regional climates and crop types, supporting a diverse range of agricultural applications.
- **Easy Integration**: Solutions that can easily be integrated into existing agricultural infrastructure or used in new construction projects with minimal disruption.

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

References:

1. Geothermal Technologies Office, U.S. Department of Energy, https://energy.gov/eere/geothermal
2. GeoVision: Harnessing the Heat Beneath our Feet, Geothermal Technologies Office, U.S. Department of Energy, Sub-Action 1.3.5: Improve Well Life Cycles, https://www.energy.gov/eere/geothermal/geovision

C60-07. ENHANCED GEOTHERMAL SYSTEMS DATA UTILIZATION

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: YES	Accepting STTR Fast-Track Applications: YES

Enhanced Geothermal Systems (EGS) are engineered geothermal reservoirs, created where there is hot rock (175-300+°C), but little to no natural permeability and/or fluid saturation. During EGS development, subsurface permeability is enhanced via safe, well-engineered reservoir stimulation processes that re-open pre-existing fractures, create new ones, or a combination of both. These open conduits increase permeability and allow fluid to circulate throughout the hot rock. The fluid transports the otherwise stranded heat to the surface where clean, renewable electricity can be generated with current power generation technologies. Awards made under this subtopic will be funded, in whole or in part, with funds appropriated by the Infrastructure Investment and Jobs Act [1], more commonly known as the Bipartisan Infrastructure Law (BIL). BIL section 41007 (a) authorizes the DOE Geothermal Technologies Office (GTO) to carry out activities under section 615(d) (Enhanced Geothermal Systems Demonstrations) of the Energy Independence and Security Act of 2007, as amended by the Energy Act of 2020 (42 U.S.C. 17194(d) (EISA 2007). EISA 2007 authorizes GTO to support Enhanced Geothermal Systems (EGS) pilot projects that collectively demonstrate EGS in different geologic settings, using a variety of development techniques and well orientations, at sites where subsurface characterization or geothermal energy integration analysis has been conducted.

These pilot demonstration projects will also enable investments that maintain progress towards GTO's Enhanced Geothermal Shot [2], an effort to dramatically reduce the cost of Enhanced Geothermal Systems (EGS)—by 90%, to $45 per megawatt hour by 2035.

a. **High Temperature Elastomers for Enhanced Geothermal Applications (**

Applications under this subtopic should focus on challenges related to improving the functionality, reliability, and durability of elastomeric materials designed for use in harsh downhole environments specific to geothermal EGS development in conditions with elevated temperatures of greater than 250°C for long-term applications (months to years) and 300°C for shorter duration applications (days to weeks), including superhot/supercritical EGS resources with temperatures greater than 375°C. Common reasons for failure include thermal and chemical degradation, mechanical stress/fatigue, and abrasion.

Specifically of interest are elastomers and other advanced polymeric materials (nanocomposites, etc.) for o-rings, seals, etc. for use in zonal isolation devices/packers, downhole pumps/valves/motors, and other wellbore/reservoir monitoring tools. Improvements in elastomeric materials will enable advancements in wellbore integrity, zonal isolation, permeability enhancement, and interpretation of subsurface signals.

Applications must be responsive to the topic of improving elastomeric materials for use in geothermal wells specifically. Applications focusing on development of non-elastomeric materials for tools/components, or gathering of data that is not of interest under this subtopic via surface/downhole sensors will be deemed non-responsive.

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

References:

1. Infrastructure Investment and Jobs Act (BIL), Public Law 117-58 (November 15, 2021). https://www.congress.gov/bill/117th-congress/house-bill/3684.
2. Enhanced Geothermal Shot, https://www.energy.gov/eere/geothermal/enhanced-geothermal-shot

C60-08. 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, resilient energy economy, creating jobs, and addressing the climate crisis, which are top priorities of the Biden Administration. Activities are aligned with the U.S. National Clean Hydrogen Strategy and Roadmap, required in the November 2021 Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law (BIL), which articulates the potential for 10 million metric tons per year (MMT/yr) of clean hydrogen by 2030, 20 MMT/yr by 2040, and 50 MMT/yr by 2050.[2] Analyses show that achieving these goals could results in 100,000 jobs by 2030 and enable 10% of economy-wide greenhouse gas reductions by 2050, contributing to the Administration's net zero emissions goal by 2050.

To achieve the goals in the national strategy, HFTO coordinates across DOE and other agencies to address key challenges across the value chain from clean hydrogen production to end use. Activities funded by HFTO 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 funded by HFTO and the Office of Clean Energy Demonstrations (OCED) address the new clean hydrogen provisions of the BIL which includes $9.5 billion for 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

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[2] National Clean Hydrogen Strategy and Roadmap, U.S. National Clean Hydrogen Strategy and Roadmap (energy.gov)

[3] Hydrogen Shot | Department of Energy, https://www.energy.gov/eere/fuelcells/hydrogen-shot

[4] H2@Scale | Department of Energy, https://www.energy.gov/eere/fuelcells/h2scale

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

DOE seeks applications in the following subtopics:

- Safety Technologies for Large-Scale Hydrogen Deployments
- Novel Concepts for Low-Energy, Low-Cost Hydrogen Loss Mitigation
- Durable, Efficient, and Low-Cost PEM Fuel Cell Cathode Catalysts for Heavy-Duty Transportation Applications

<u>BIL Funded</u>

- Membranes and Separators for Alkaline Electrolyzers
- Innovative Manufacturing Concepts to Support Scale-Up of Medium- and Heavy-Duty Fuel Cell Trucks
- *In Situ* Diagnostic Tools for Clean Hydrogen Production
- Power Electronics Enabling Conversion of Low-Cost Intermittent Electricity to Low-Cost Hydrogen
- Facilitate the Development and Expansion of a Robust Supply Chain for Hydrogen and Fuel Cell Systems and Components

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[5] 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

a. Safety Technologies for Large-Scale Hydrogen Deployments

As deployment of hydrogen technologies scale across sectors, the management of potential hazards is expected to become more complex. Design and operation of hydrogen facilities are conducted in accordance with relevant codes and standards to enable safety.[6] For example, facilities incorporate sensors that alert operators if unsafe conditions arise. Individual pieces of equipment (e.g., electrolyzers, storage vessels) often incorporate automatic shutdown devices (e.g., shutoff valves) to isolate and manage specific hazards. However, many systems lack the integration of complex information from multiple aspects of a hydrogen facility to enable a rapid response such as shutting off hydrogen flows. Additionally, ultra low-cost technologies may lack key safety indicators to communities near large-scale hydrogen deployments. This subtopic is seeking proposals for the development of low-cost, commercially viable, safety technologies that focus on either 1) rapid response systems for hydrogen facilities and equipment, or 2) user-friendly sensors that can be deployed by community stakeholders (e.g., first responders, community members).

1) Rapid Response Safety Systems for Hydrogen Facilities and Equipment

For this focus area, DOE is seeking systems that can be installed at large-scale hydrogen facilities to enable a rapid automatic response when unsafe conditions are detected. Of interest are technologies that integrate with data-related and analytical equipment. Proposals may include the development and validation of best practices associated with placement and integration of sensors at facilities to enable a rapid response. Metrics of interest for continuous measurement include pressure, temperature, flow rate, and hydrogen concentration. Proposed safety systems must include real-time monitoring, automatic activation, and a simple manual override, and be broadly scalable and compatible with data collection software. Proposed systems must comply with relevant codes, standards, and regulations, including but not limited to those developed by National Fire Protection Association (NFPA),[7] National Standards Institute (ANSI)[8], the Occupational Safety and Health Administration (OSHA),[9] and the American Society of Mechanical Engineers (ASME).[10] Proposed systems that duplicate technologies already in use for specific components (e.g., pressure relief valves), are based on qualitative metrics (e.g., colorimetric), or rely on measurements that are inherently low in precision (e.g., fence-line style monitoring) are not of interest.

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[6] DOE's Hydrogen and Fuel Cell Technologies Office (HFTO) funds R&D to inform codes and standards that guide design of hydrogen equipment, and to advance the performance of sensors. More information about HFTO's Safety, Codes, & Standards program is available here.
[7] NFPA 2 Hydrogen Technologies Code, NFPA 55 Compressed Gases and Cryogenic Fluids Code
[8] ANSI/CSA HGV 4.9 Hydrogen Fueling Nozzles and Receptacles
[9] OSHA 1910.103 Hydrogen
[10] ASME B31.13 Hydrogen Piping and Pipelines

2) User-Friendly Safety Sensors for Community Stakeholders

For this focus area, DOE is seeking proposals to develop and demonstrate ultra low-cost and reliable safety sensors that can be widely deployed and easily operated by community stakeholders without significant hydrogen training (e.g., first responders, community members). Proposed technologies must clearly indicate to the user whether the hydrogen concentration in the area is in the hazardous range and must meet the DOE targets for safety sensors.[11] Applicants should describe how the proposed sensors will be able to deliver rapid, reliable, and reproducible qualitative as well as quantitative results. Proposals may include technologies that are capable of reporting safety metrics for other gases in addition to hydrogen (e.g., methane, nitrous oxides, carbon monoxide/dioxide). Proposed technologies may be standalone or communicate with a central monitoring system and may integrate existing sensor technologies and/or components. Phase I should emphasize community-engaged science (e.g., development of the technology with input from a community organization to ensure wide accessibility), with plans to demonstrate or validate the technology with community stakeholders in Phase II.

Questions – Contact: Jacob Englander, jacob.englander@ee.doe.gov

b. Novel Concepts for Low-Energy, Low-Cost Hydrogen Loss Mitigation

Stakeholders within the environmental and atmospheric modeling community have recently raised concerns that the indirect impacts of hydrogen on global warming can reduce the projected decarbonization benefits of displacing fossil hydrocarbons with clean hydrogen. Releases or leaks of hydrogen can indirectly generate a warming effect by reacting with other chemicals in the atmosphere in a manner that produces or extends the lifetime of greenhouse gases (GHGs). Additionally, unexpected releases of hydrogen can adversely impact the economic viability of refueling stations and other hydrogen infrastructure. DOE is working to enable mitigation of hydrogen losses through all aspects of its life cycle from production to end-use and in varied handling modes such as transport or storage.

Hydrogen losses can occur from intentional releases such as liquid hydrogen boil-off, depressurization of delivery trailers, and purging of transfer lines, or from unintentional releases such as leaks or safety system activations. For instance, supplying and operating a refueling station for heavy-duty vehicles may lead to boil-off losses at all stages of the value chain starting at the liquefaction plant, from the delivery truck, and the refueling station dewar, in addition to losses during dispensing from the liquid pump and the dispensing interface. Though compressed gas has been widely adopted in onboard vehicle storage, cryogenic storage solutions

[11] Current DOE Hydrogen Sensor Targets are available here.

(e.g., cryo-compressed, subcooled liquid) are increasingly of interest to stakeholders which introduces potential boil off loses from vehicle. Components that should be prioritized for boil-off mitigation solutions include, but should not be limited to, cryopumps, dispensers, dewars, and onboard cryogenic tanks.

Commonly, losses of liquid hydrogen at refueling stations during purges and transfers can range from less than 0.5 kg/hour to 3 kg/hour depending on the heat load into the system and cryopump status at the station.[12] Vented hydrogen temperatures can range from ~25 K when vented directly from the liquid hydrogen dewar to near ambient temperature (300 K) when vented from a transfer hose. Hydrogen suppliers have to account for the financial impact of regular hydrogen losses which can lead to an increase in the price consumers pay at the pump.

Several approaches have been implemented to mitigate the GHG effects of vented hydrogen. When the vented hydrogen can be recaptured after venting, the gas can be reliquefied into the storage dewar, distributed locally for use near the station, fed into a recombiner to convert the hydrogen gas into an atmospherically benign chemical such as steam, or used in a fuel cell to generate power for local use or grid export. Another technology commonly used at hydrogen storage facilities besides recapture is flaring, in which hydrogen is burned as it is vented which avoids the aforementioned warming effects and any potential delayed ignition hazards. There are costs associated with these approaches via either additional energy input in the case of reliquification and capture, or loss of usable hydrogen via recombiners or flaring.

This subtopic seeks to develop novel components and approaches (solutions) that significantly reduce or eliminate hydrogen losses. Solutions should handle a wide range of flow rates, typically around 1-3 kg/hour, but higher rates can be encountered. Solutions should also be compatible with the temperature range listed above.

Phase 1 applications must compare the proposed solution to current loss mitigation technologies. Applicants must clearly describe the proof of concept through solution design as well as relevant physical modeling. Proposals should address any needed changes to associated infrastructure (e.g., piping, storage vessels, vent stacks, etc.). Proposals should also include technoeconomic analyses of the lifecycle cost of the solution. These analyses should parameterize the cost of hydrogen.

In Phase II, applicants are expected to develop, fabricate, and test the solution proposed in Phase I in relevant conditions.

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

[12] https://www.energy.gov/sites/default/files/2018/07/f53/fcto_webinarslides_boil_off_losses_062618.pdf

c. Durable, Efficient, and Low-Cost PEM Fuel Cell Cathode Catalysts for Heavy-Duty Transportation Applications

This subtopic solicits proposals for novel and innovative concepts that advance the development and integration of oxygen reduction reaction (ORR) cathode electrocatalysts for use in heavy-duty direct hydrogen polymer electrolyte membrane (PEM) fuel cells, with a focus on high durability and high efficiency, particularly at high temperature operation (100-120 C). Catalyst innovations can encompass, but are not limited to, novel alloys, support structures, and support materials.

Medium- and heavy-duty PEM fuel cell electric vehicles operating on hydrogen offer several advantages over incumbent technologies, including higher efficiency, reduced emissions, higher torque, and no noise pollution. Medium- and heavy-duty truck applications require a lifetime of up to one million miles, and therefore require fuel cells with innovative components with enhanced durability. Significantly longer vehicle lifetimes and range requirements also mean that hydrogen fuel costs comprise a greater proportion of vehicle lifecycle cost. As such, fuel cell efficiency is a key parameter for economic viability. Operation at higher temperatures (100-120 C) can facilitate simplification of the stack/system design due to easier heat rejection as well as elimination/modification of humidification subsystems. However, to date, catalysts specifically designed to take advantage of the benefits of operating at elevated temperatures have not been fully explored.

PEM fuel cell membrane electrode assemblies (MEAs) rely on expensive Platinum Group Metals (PGM) as catalysts within the electrodes. A critical path to reducing fuel cell cost is to reduce the amount of PGMs used in fuel cells and enhance ORR activity while maintaining fuel cell durability and efficiency. For state-of-the-art MEAs, durability and power output decrease with lower PGM loading. This makes it difficult to meet the 2030 DOE target of 25,000 hours durability for medium- and heavy-duty transportation applications while simultaneously meeting targets for system cost ($80/kW) and efficiency (68% peak).[13] In the most demanding applications, the conditions include operation in the presence of fuel and air impurities, starting and stopping, freezing and thawing, and humidity and load cycling that result in mechanical and chemical stresses on fuel cell materials, components, and interfaces.

To expedite heavy-duty fuel cell competitiveness, DOE established the Million Mile Fuel Cell Truck consortium (M2FCT), which includes national labs in partnership with universities and industry to accelerate research and development that would enable

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[13] Hydrogen Class 8 Long Haul Truck Targets.
https://www.hydrogen.energy.gov/pdfs/19006_hydrogen_class8_long_haul_truck_targets.pdf

meeting a fuel cell durability of a million miles. M2FCT is a large-scale, comprehensive effort to enable widespread commercialization of fuel cells for heavy-duty applications with a focus on achieving aggressive targets for fuel cell MEAs that meet efficiency, durability, and cost. Successful applicants are encouraged to collaborate with M2FCT where possible, including testing and utilizing appropriate accelerated stress tests (ASTs) as part of a Phase I program. Should the program advance to Phase II and beyond, more extensive collaboration with M2FCT would be required. Proposed catalyst designs submitted in response to this subtopic must demonstrate significant progress, when integrated in an MEA, toward exceeding the M2FCT 2025 MEA target of 2.5 kW/g_{PGM} power output (1.07 A/cm^2 current density at 0.7 V) after running a heavy-duty AST equivalent to 25,000 hours. The target is for MEA-level performance with total PGM loading constrained to 0.3 mg/cm^2. MEA test conditions are: 100-120 C, 2.5 atm, stoichiometry ratio: 1.5 cathode/2 anode, as low humidity as is reasonable, and integral cell conditions.

Phase I proposals should provide details of novel low-PGM (total MEA loading of $\leq$0.3 mg_{PGM}/cm^2) cathode oxygen reduction catalyst synthesis, MEA integration approach for enhanced performance, MEA testing, and substantial evidence of how the approach improves durability and efficiency of low-cost fuel cells under realistic conditions. Novel catalysts proposed in this subtopic should aim to directly address key challenges associated with the increased temperature requirements. This must include increased resistance towards carbon corrosion as well catalysts optimized for operation in the inherently dryer environments of this temperature range. PGM-free catalysts are identified as not of interest towards this subtopic.

Questions – Contact: Gregory Kleen, gregory.kleen@ee.doe.gov

d. Membranes and Separators for Alkaline Electrolyzers

Several diverse alkaline water electrolyzer technologies are being developed domestically, with the potential to achieve the Hydrogen Shot target of \$1/kg-H_2. While conventional liquid alkaline electrolyzers utilize porous separators and highly concentrated alkaline electrolyte (~7 M KOH), emerging alkaline electrolyzer technologies employ alkaline exchange membranes (AEMs) and less concentrated electrolytes (e.g., ≤ 1 M KOH or K_2CO_3). Recently, the distinction between these two types of alkaline electrolyzers has become less defined as innovative designs combine positive attributes of each to achieve higher current densities, mitigate shunt currents, enable dynamic operation on variable renewable power, operate at differential pressure, or enable other advantageous operating modes.

In most alkaline electrolyzers, key advantages include the alkaline environment, which enables the potential use of non-precious metal catalysts and less expensive metal interconnects, as well as the use of non-perfluorosulfonic acid (non-PFSA) ionomers, membranes, and separators.[14] However, a critical limitation in the development of high-performance, long-lifetime alkaline electrolyzers is the fabrication of a mechanically robust and chemically stable separator material that can endure long-term operation in supporting electrolyte while maintaining high hydroxide ion conductivity (or low area-specific-resistance) at elevated temperatures and pressures.[15]

In this subtopic, applicants will develop membranes or other separator materials for alkaline electrolyzers that have low area-specific-resistance and are chemically and mechanically stable in low (≤ 1 M) or high (~7 M) KOH concentrations (depending on the specific electrolyzer technology) and at elevated pressure (up to 30 bar). Technical targets for material properties and performance were developed to enable commercialization of economically viable alkaline electrolyzers. Novel membranes or other separators developed through this subtopic should address the following properties and characteristics, including:

- Chemical and mechanical stability at ≥ 60 C, preferably at least 80 C
- Performance in an electrolyzer cell of >2 A/cm^2 at 1.8 V
- Cell degradation rate of <4 mV/1000 hours with testing for a minimum of 500 hours
- High OH^- conductivity and low area-specific-resistance over relevant temperatures and electrolyte concentrations
- Low swelling and low solubility in the electrolyte
- Low creep under a range of stress, temperature, pressure, and electrolyte concentrations
- Low permeability to gases, including both H_2 and O_2, at relevant pressures

Phase I projects must include measurement of chemical and physical properties to demonstrate feasibility of meeting the properties and characteristics specified above. Specific criteria for material properties must be tailored to the specific alkaline electrolyzer technology and must be clearly defined in the application. Membrane stability testing must be conducted in line with established best practices.[16] Testing of novel membranes and separators in an electrolyzer cell in Phase I is strongly encouraged, in addition to projections of the impact of the development on the levelized cost of hydrogen for a range of electricity costs.

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[14] Ayers, K., Danilovic, N., Ouimet, R., Carmo, M., Pivovar, B., and Bornstein, M. (2019). Perspectives on Low-Temperature Electrolysis and Potential for Renewable Hydrogen at Scale. Annu. Rev. Chem. Biomol. Eng. 10, 219–239. doi:10.1146/annurev-chembioeng-060718-030241

[15] Park, E. J., Arges, C. G., Xu, H., and Kim, Y.S. (2022). Membrane Strategies for Water Electrolysis ACS Energy Lett. 2022, 7, 3447−3457. doi.org/10.1021/acsenergylett.2c01609

[16] Arges CG, Ramani V, Wang Z and Ouimet RJ (2022) Assessing the Oxidative Stability of Anion Exchange Membranes in Oxygen Saturated Aqueous Alkaline Solutions. Front. Energy Res. 10:871851. doi: 10.3389/fenrg.2022.871851

Successful Phase I awards may be selected for Phase II, which would address long-term durability and the development of manufacturing processes that enable DOE's 2026 cost target of \$2/kg-H_2.

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

e. Innovative Manufacturing Concepts to Support Scale-Up of Medium- and Heavy-Duty Fuel Cell Trucks

This subtopic solicits proposals for novel and innovative concepts that address challenges and bottlenecks to the manufacturing scale-up of high quality and durable stacks, cells, membrane electrode assemblies (MEA), and MEA components for medium- and heavy-duty polymer electrolyte membrane (PEM) fuel cells.

Currently stacks and cells are fabricated using largely manual or semi-automated methods, whereas fully automated methods are needed to meet initial market volumes. MEA components are in many cases fabricated using continuous manufacturing methods, e.g., roll-to-roll, but the equipment and processes may not be fully optimized for current PEM fuel cell materials and structures.[17] Existing equipment and methods may also not be amenable to novel MEA, cell, or stack structures that may provide increased manufacturability, efficiency, and durability, or decreased cost. In addition, efficient and high throughput testing and conditioning of stacks post-assembly is understood to be an ongoing challenge. Areas of interest include innovative approaches to accelerate conditioning and validation, and improved equipment and electronics for the test and conditioning steps. DOE seeks proposals that will assist the hydrogen community in increasing manufacturing capacities so that near-term production targets of 20,000 stacks/year (6 stacks/hour, 2,400 MEAs/hour) for medium- and heavy-duty fuel cells[18] are enabled. This target is the first step toward the production volumes needed to meet the ultimate system cost target of \$80/kW (at 25,000-hour durability).

Phase I proposals must provide details of the process or equipment technology concept, the approach to validating the feasibility of the concept at a prototype scale, and evidence (e.g., initial techno-economic analysis) of how the concept will facilitate increased manufacturing throughput (including addressing bottlenecks such as conditioning and testing/validation of components/systems) toward the near-term 20,000 stacks/year target as well as ultimate system cost and durability targets. Phase II proposals are envisioned to include prototype demonstration using relevant materials and/or under relevant processing or testing conditions,

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[17] Manufacturing Automation and Recycling for Clean Hydrogen Technologies Virtual Experts Meeting, May 2022. (https://www.energy.gov/eere/fuelcells/manufacturing-automation-and-recycling-clean-hydrogen-technologies-experts-meeting)
[18] DE-FOA-0002922 (https://www.energy.gov/eere/fuelcells/bipartisan-infrastructure-law-clean-hydrogen-electrolysis-manufacturing-and-0)

fabrication and in-situ testing of multiple MEAs (if addressing this subtopic area), and detailed cost analysis. Applicants may consider coordination or collaboration with the HFTO R2R consortium[19] regarding MEA process science and manufacturing and/or the M2FCT consortium[20] to assist with in situ cell testing (in a Phase II proposal), though such collaboration is not required.

Proposal topics that are not of interest include: bipolar-plate protective coatings and fundamental catalyst, membrane, or MEA development.

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

f. *In Situ* Diagnostic Tools for Clean Hydrogen Production

Development of new, large-scale water electrolysis projects, whether through the Hydrogen Hubs or other hydrogen related initiatives, will present both challenges and opportunities critical to meet the DOE's Hydrogen Shot targets of \$1/kg-H_2 produced.[21] Operational lifetime and reliability of electrolyzer systems can impact the achievement of the Hydrogen Shot goal as poor durability can necessitate replacement of costly stack and system components. Currently, approximately 80% of electrolyzer failures in the field are due to water quality issues.[22] Additionally, small punctures in individual cells can allow dangerous mixtures of hydrogen and oxygen gases.[23] Furthermore, as individual cells fail, further strain can be placed upon other cells within the stack, leading to a cascading failure.

In situ diagnostic tools or monitoring devices for electrolyzer operation could improve reliability and consequently reduce the overall cost of hydrogen production. However, current diagnostic tools are inadequate to address many of the needs for these new electrolyzer systems. Water conductivity meters can show an ostensibly adequate conductivity for these systems, while not detecting impactful levels of polyvalent cations, known to be most damaging to PEM electrolyzer systems, and cannot detect the presence of nonconducting, but potentially still damaging, water contaminants.[22] Flammable gas meters can detect dangerous levels of hydrogen outside of the stack, but cannot detect reactant gas mixtures within the stack until it is too late to prevent catastrophic failure. Current power electronics allow for performance monitoring of stacks but are unable to resolve losses to individual cells.

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[19] R2R website: https://www.energy.gov/eere/fuelcells/articles/doe-national-laboratory-consortium-advance-high-volume-manufacturing
[20] M2FCT website: millionmilefuelcelltruck.org
[21] https://www.energy.gov/oced/regional-clean-hydrogen-hubs-0
[22] Elliot Padgett et al 2024 J. Electrochem. Soc. 171 064510
[23] S. E. Wismer et al 2024 Intern. J. Hydro. Ener. 89 P. 1280-1289

In this subtopic, applicants will demonstrate new *in situ* diagnostic tools to address the needs of electrolyzer system operators and manufacturers. These could include items such as:

- Power electronics which can enable cell-level electrochemical impedance spectroscopy (EIS) or which can employ novel electrochemical techniques to monitor cell performance
- *In situ* sensors for detecting rising or dangerous levels of water contamination, such as selective ion probes
- Optical tools, such as thermal or hyperspectral imaging, to monitor cell performance or for the presence of small fires in real time
- Compact gas detectors for monitoring H_2/O_2 ratios within the stack

Applicants must clearly justify the need for the proposed *in situ* diagnostic tool within their application. During Phase I, applicants must demonstrate their ability to detect and prevent a specified failure mode on a cell- or small stack-level, while also demonstrating the ability to incorporate their tool within existing systems. Technoeconomic analysis comparing the cost of the tool with the cost savings from improved reliability is strongly encouraged during Phase I. Successful Phase I applicants may be selected for Phase II, which would support the manufacturing their tool for wide scale deployment.

Questions – Contact: McKenzie Hubert, mckenzie.hubert@ee.doe.gov

g. Power Electronics Enabling Conversion of Low-Cost Intermittent Electricity to Low-Cost Hydrogen

This subtopic solicits novel and innovative power electronics concepts that enable efficient and dynamic electrolyzer operation in conjunction with or independent of a connection to the electrical grid. The primary cost contributor to clean hydrogen produced at large scales via electrolysis is the cost of the input electricity.[24] Low-cost electricity may be available via the electrical grid during periods where generation exceeds demand and the price of electricity falls. In excess generation cases where matched supply and demand are not obtainable, utilities must reduce supply to maintain grid stability, often by curtailing renewable generation. With significant grid-tied electrolyzer capacity capable of dynamic response, curtailment may be minimized and economic production of clean hydrogen maximized. Large scale utilization of low-cost electricity directly supports HFTO's established cost targets for hydrogen production, which include costs of \$2/kg in 2026 and the Hydrogen Earthshot Target of \$1/kg in 2031.[25]

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[24] DOE Hydrogen Program Record 24005: Clean Hydrogen Production Cost Scenarios with PEM Electrolyzer Technology (energy.gov)

[25] Hydrogen Shot | Department of Energy

Conventional grid-tied electrolyzer power supplies that convert alternating current (AC) electricity to the direct current (DC) required by the electrolyzers, are often high-power rectifiers which were designed for stable industrial operation in long established industries like chlor-alkali production or metals refining. Such systems are generally designed for a narrow operating range and may not respond efficiently or rapidly to the dynamic power inputs characteristic of excess renewable electricity, leaving hydrogen producers unable to capture a large portion of intermittent low-cost electrical power. Shifting away from legacy hardware architectures and adopting AC/DC and/or DC/DC conversion hardware designed for dynamic operation and similar to that used for maximizing photovoltaic energy production (e.g., DC/DC converters, maximum power point trackers, power conditioning, etc.), enables producers to more efficiently capture and use renewable electricity. A further advantage to this hardware shift is that in some cases, additional low-cost electricity may be available for hydrogen production by coupling renewable generation directly with electrolyzers (i.e., without first connecting to the grid). In such cases, it may also be possible to reduce or avoid the costs associated with connection of the renewable generation to the grid, avoid delays related to permitting and/or grid connection, and/or avoid inefficiencies from AC/DC conversion.

Current commercial options for power electronics optimized for dynamic electrolyzer operation are limited, though power electronics systems and base components providing similar functionality are manufactured. This subtopic seeks innovative concepts which combine currently available power electronics components in novel ways (and/or with novel controls) to provide DC output power to electrolyzer stacks using variable/intermittent input electricity. Applicants may focus system architectures on grid-independent and/or grid-connected formats and are encouraged to assess architectures and report results in terms of hardware flexibility (ability to utilize multiple forms of input power), hardware dynamic response, and estimated cost of hydrogen produced. Phase I of this effort should consist of modeling and design analysis to optimize and select the desired base modules to yield electrolyzer power electronics capable of efficient dynamic operation over a wide range (5% - 100% power for a 1 MW electrolyzer). The modeled system should consist of commercially available components or components available on the U.S. domestic market before the end of 2025. Phase II efforts should focus on building and bench testing a scaled down prototype system comprised of the optimal base modules at 1/10 or 1/100 scale with respect to power level (1 MW).

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

h. Facilitate the Development and Expansion of a Robust Supply Chain for Hydrogen and Fuel Cell Systems and Components

The hydrogen and fuel cell industry is rapidly expanding with diverse applications across sectors in industry (e.g., chemicals, steel), energy storage, stationary power, and heavy-duty transportation (e.g., trucks, marine, rail, aviation) and covers the entire value chain from production to end use with an estimated global revenue of $2.5 trillion.[26] However, there are few mechanisms that provide visibility into the domestic supply chain for components such as catalysts, membranes, bipolar plates, balance-of-plant components, and other systems or subsystems.

In this subtopic, DOE is seeking proposals to facilitate the development of a robust domestic supply chain for hydrogen and fuel cell systems and components. Small businesses and partners are solicited with experience in tools and approaches to datamining, identifying and publicizing supply chain components and developers, and enhancing opportunities for resiliency and commercialization. The result of the project will be a platform (e.g., website) that houses a comprehensive database of hydrogen and fuel cell system part and component vendors with a U.S. manufacturing footprint, creates a community for matching suppliers with system developers, and provides transparency to the industry on potential gaps and on the evolving landscape as new suppliers enter the market.

The applicant should be familiar with the hydrogen and fuel cell industry and demonstrate access to the necessary resources to not only identify known suppliers but identify new or underexposed suppliers. For example, the applicant should demonstrate the capability to engage with various stakeholders through mechanisms such as surveys, interviews, meetings, datamining, and other communication approaches, as appropriate, to determine the state of the hydrogen and fuel cell supply chain accurately and identify pathways to enhance it. A team approach comprised of members with broad expertise in the hydrogen and fuel cell industry is suggested. Applicants are encouraged to propose a plan that best leverages funding to create a sustainable business model to support the effort after the project is completed. The proposed idea(s) should benefit the entire hydrogen and fuel cell community; therefore, proposals that address supply chains with broad impact will be preferred. Efforts that build upon HFTO's previous work in this area and collaboration with relevant projects are strongly encouraged.[27]

Applicants are also highly encouraged to think outside-the-box and propose novel ideas, to accelerate progress in identification, commercialization, and dissemination of suppliers to enable a robust, commercially successful and resilient domestic supply chain. Innovative efforts could include the utilization of artificial intelligence approaches to expedite data collection, screening of potential suppliers, matchmaking with end users or developers, and information sharing. For the specific outreach activities proposed by the applicant, metrics should be provided that

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[26] Hydrogen Council Scaling Up Report: https://hydrogencouncil.com/en/study-hydrogen-scaling-up

[27] https://hfcnexus.com/

illustrate the potential impact on the robustness of the supply chain (economies of scale, etc.). Many of the necessary sub-components are already commercially available but not necessarily visible in the industry. Thus, a major focus is identifying the suppliers and making them readily visible and accessible to the system and subsystem manufacturers and identifying bottlenecks or key supply chain constraints.

During Phase I, applicants must deliver an updated database covering the spectrum of hydrogen and fuel cell technologies, particularly on components and system integrators. Successful Phase I applicants may be selected for Phase II, which would support platform/database expansion, demonstration of self-sustainability for the database, and the incorporation of advanced approaches for identifying and connecting suppliers with end users.

Note that this subtopic is not intended to be a research and development project for a particular part or component. Rather this subtopic is focused on the entire supply chain as related to the hydrogen and fuel cell industry including, but not limited to: fuel cell stack and system components (catalysts, membranes, gas diffusion media, membrane electrode assemblies, bipolar plates, humidifiers, air management, balance-of-plant components, etc.), electrolyzers (stacks and system components including balance of plant), reformers, hydrogen storage systems (high pressure tanks, carbon fiber, valves, etc.), and hydrogen infrastructure components (compressors, nozzles, sensors, etc.).

Questions – Contact: Greg Kleen, gregory.kleen@ee.doe.gov

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C60-09. 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

This topic will be providing feedback to responsive Letters of Intent.

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;
- 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 must 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. Destruction Technologies for PFAS in Biosolids

The U.S. Environmental Protection Agency (EPA) estimates the direct greenhouse gas (GHG) emissions from Water Resource Recovery Facilities (WRRFs) – previously known as either Wastewater Treatment Plants (WWTPs) or Publicly-Owned Treatment Works (POTWs) – at approximately 44 Mtons CO_{2eq}. The bulk of these direct emissions are comprised of N_2O and CH_4, accounting for approximately 6% and 3% of total U.S. emissions for each respective GHG [2]. These estimates are widely considered to be low, as they do not consider the full lifecycle of the sludge/biosolids characteristic of WRRF operations in particular. Further, contamination of sludge and biosolids with substances such as per- and poly-fluoroalkyl substances (PFAS) are increasingly constraining disposal options. Therefore, this subtopic, in support of the DOE Energy-Water Nexus crosscut, focuses on a combination of PFAS destruction in sludge and biosolids, as well as sludge volume reduction, to address problems of growing importance for WRRFs.

PFAS, also known as "forever chemicals," are a class of emerging contaminants that are difficult to degrade or destroy, resisting most conventional wastewater treatment processes [3]. PFAS treatment solutions for aqueous matrices (e.g., groundwater, drinking water) have advanced in recent years, but technologies for solids treatment are lacking. End uses of biosolids in the U.S. include approximately 50% land application, 35% landfill, and 15% incineration [4,5].

In 2023, the EPA released screening levels for PFAS in drinking water [6]. A risk assessment for PFAS-contaminated biosolids, which would serve as the basis for pollutant limits and monitoring requirements for PFAS in biosolids, is expected in 2024 [7]. Additionally, several states have begun to implement their own respective restrictions on land application and/or landfilling of PFAS-contaminated biosolids [8,9,10]. The biological nature of biosolids generated from WRRFs introduce additional issues at hazardous and/or industrial landfills, which are equipped to handle materially different waste, and generally do not have methane capture systems [3]. Effective sludge/biosolids treatment necessitates destruction of PFAS compounds through complete fluorine mineralization via disruption of the carbon-fluorine bonds [11]. Destruction of PFAS with minimal to no formation of products of incomplete destruction (PIDs) will be crucial to eliminate its threat to human health and the environment. Current state-of-the-art PFAS destruction technologies for solids and biosolids are poorly studied and understood. Development of energy efficient, cost-effective PFAS destruction technologies that reduce sludge volume seeks to address these challenges [3].

Achieving sludge and biosolids mass reduction would lessen emissions associated with transport and disposal, such as CH_4 in landfills and potential N_2O in land application scenarios and could include additional benefits. Further, as solids are typically transported for disposal in diesel trucks, waste reduction would decrease air pollutants from diesel emissions—particularly important for disadvantaged communities which often live near WRRFs. As solids disposal can comprise as much as 40-50% of WRRF operating costs, waste reduction may also lessen ratepayer pressures for WRRFs [12,13,14].

In this subtopic, IEDO seeks proposals to advance scalable PFAS destruction technologies for biosolids that substantially reduce overall sludge volume. Destruction efficacy is determined through minimization of PFAS and other toxic byproducts in the output at or below EPA maximum contaminant levels (MCLs) for drinking water [6, 15]. The following must be reported as part of competitive proposals:
The method of destruction, specifically complete disruption of the carbon-fluorine bonds, must be demonstrated.
Total effluent concentrations from WRRFs tend to exceed influent levels as wastewater treatment processes often transform PFAS precursors into PFAS products; therefore, fate and transport processes of influent PFAS and precursors must be characterized.
All process inputs and outputs (including PIDs) must be characterized for both PFAS and non-PFAS fluorocarbons to understand potential harmful releases of byproducts.
Fluorine (inorganic) mass balance must be determined and closed to the degree feasible.

Applications must demonstrate progress in Phase I and achievement in Phase II of the following performance and cost targets

	Objective/Goal	Metric	Target	Baseline
Required	Minimize toxic end-products	Effluent PFAS[28] and PIDs	Drinking water MCLs	*Applicant-defined*
	Reduce overall sludge volume	Sludge volume reduction	80%	Influent into solids treatment
Stretch	Minimize energy usage	Energy usage (kWh) per dry ton	*Applicant-defined*	*Applicant-defined*
	Minimize cost	Cost (USD) per dry ton	*Applicant-defined*	*Applicant-defined*

[28] Analytical list includes 40 PFAS compounds cited in EPA Method 1633 [16].

Proposals must minimize effluent PFAS and toxic byproducts and reduce sludge volumes by a minimum of 80%. The application should provide a path to scale up in potential Phase II follow-on work. Additional project requirements include:

- Use real biosolids in testing destruction efficacy;
- Treat a minimum of 5 dry kilograms per day of biosolids (pilot-scale);
- Identify approved analytical testing methods for sample analysis (i.e., EPA Method 1633); and
- Conduct a lifecycle analysis (LCA) and a technoeconomic assessment (TEA) as part of the initial application, and update each at the end of Phase I and Phase II.

Incineration technologies or removal or degradation technologies that do not include complete destruction are not of interest.

Questions – Contact: Mark Philbrick, mark.philbrick@ee.doe.gov

b. Reducing Environmental Impacts of Chemicals Manufacturing

The United States is the world's second-largest chemicals producer, with ~$517B of products produced annually, totaling 14% of the global chemicals market. It is responsible for converting raw materials into more than 70,000 diverse products, which are essential to several sectors of the U.S. economy, including agriculture, manufacturing, pharmaceuticals, and energy. Though chemicals are critical to the production of manufactured products, chemical production is heavily dependent on fossil resources and energy intensive processes, accounting for an estimated 8,169 trillion British thermal units (TBTU) of primary energy consumption in 2018 (including both feedstock and fuel use) and an associated 332 MMT of CO_2e GHG emissions (including both process and energy-related emissions) [18]. Beyond its contribution to GHG emissions, chemicals manufacturing leads to the release of pollutants that present known or reasonably suspected risks to human health and the environment [19].

IEDO is committed to working with the private sector to decarbonize the industrial sector and realize broader sustainability and efficiency improvements across the chemicals industry. These improvements have the potential to reduce the environmental footprint of the sector through reduction in land and water usage, hazardous emissions, and waste generation while also improving economics and process efficiency. Implementation of sustainable chemistry practices in chemicals manufacturing can positively influence communities near manufacturing facilities by improving local air quality and reducing risk of exposure to harmful chemicals.

In the report Sustainable Chemistry in RD&D to Transform the Chemicals Sector Roundtable [20] and IEDO's recent Scaling Sustainable Chemistry for Industry Transformation [21] forum, industry stakeholders identified barriers and opportunities for incorporating sustainable chemistry practices into the manufacturing of consumer and commercial products. The report highlights the need for scalable processes, favorable economics, and maximization of co-benefits to meet the goals of reducing energy and carbon emissions while also mitigating hazardous chemicals, toxicity, and resource intensity.

In conjunction with decarbonizing the chemicals sector, IEDO seeks to reduce the environmental impact of chemicals manufacturing processes by developing transformative technologies and processes that reduce or eliminate toxic byproducts and minimize resource consumption. This subtopic is seeking technologies that mitigate the environmental impacts of chemical manufacturing by addressing the following needs:

- Reduce water demand for processes involved in chemical manufacturing: Significant volumes of water are required for many applications in chemicals manufacturing including water for cooling towers, wash water, and feed water, among others. Furthermore, many future chemical industry technologies are expected to have an increased water demand. Electrochemical manufacturing and biomanufacturing, for example, require access to large volumes of high-quality water. R&D to develop novel technologies and processes that will reduce freshwater demand or improve onsite water recycling are of interest. Proposals must include some touchpoint to the chemicals value chain, including projects that address integration challenges, development of novel unit operations, or barriers associated with upstream or downstream processes.

Objective/Goal	Metric	Target	Baseline
Reduce Water Consumption	L water consumed/kg product OR percent reduction in freshwater withdrawals from current typical process OR percent of water recycled onsite	50% Reduction	Applicant Defined

- Reduce emission of air pollutants from chemical manufacturing processes: Chemical manufacturing processes produce many air pollutants that are harmful to the environment and human health. Technologies seeking to mitigate these air pollutants from chemical manufacturing processes, including SO_x, NO_x, N_2O, VOCs, particulate matter (PM) and fluorinated gases, are of interest. Technologies may include either abatement technologies that mitigate the release of industrial waste gases into the environment for existing chemical pathways or technologies that introduce alternative routes to manufacturing chemicals that reduce specified pollutants. Chemical manufacturing processes are broadly defined to include the synthesis, purification, and fabrication of both organic and inorganic chemical products. Technologies primarily targeting reductions in CO_2, CH_4, or CO emissions are not of interest.

Objective/Goal	Metric	Target	Baseline
Reduce Air Pollutant Emissions	Ton pollutant/ton product OR % reduction pollutant from current typical process	50% reduction	Applicant Defined

Questions – Contact: Felicia Lucci, felicia.lucci@ee.doe.gov

c. Thermal Management and On-Site Energy Technologies for Data Centers

The rise in artificial intelligence, cloud computing, and other virtual technologies has significantly increased the demand for data centers and their associated electricity demand [22,23]. There are more than 5,000 data centers in the United States [24], and newer data centers, especially hyperscale data centers, can consume anywhere from 100 MW to 1,000 MW [23,25]. As a result, data center electricity consumption is expected to surge to as much as about 9% of total U.S. electricity production in 2030 (from about 4% today) [23]. DOE is interested in reducing this demand through improvements in energy efficiency and research and development of low carbon technologies that can be applied to new greenfield data centers or be retrofitted to existing data centers.

Data center operations produce a significant amount of low-grade heat and require the use of cooling equipment that can account for around 40% of a data center's total electricity use [23,26]. This equipment is typically a combination of HVAC systems and water cooling [27]. Immersion cooling and waste heat recovery systems are emerging areas that can reduce not only the energy use but also the water use of a data center [28,29].

This subtopic seeks advancements in the following Areas of Interest:

I. Efficient immersion cooling systems to improve cooling performance and reduce water use;
II. Low-carbon combined cooling and power systems that can be deployed onsite to reduce grid reliance, increase resilience, and reduce carbon footprint;

III. Efficient waste heat recovery and/or utilization systems to effectively use low-grade waste heat generated from data centers; and

IV. Other thermal management technologies.

Metrics: Required metrics for each Area of Interest above are listed in the table below. Additional applicant-defined targets and metrics appropriate to commercialization should also be included. Other possible metrics include, but are not limited to: reduce operating and/or capital expenses, increase computational performance, reduce peak load, and improved reliability.

Area of Interest	Metric Minimum Target	Metric Stretch Target
I	PUE ≤ 1.10 [30] WUE < 0.7 L/kWh CCF = 110-120% [32]	PUE ≤ 1.03 [29,31] WUE = 0 L/kWh CCF = 110-120%
II	Emissions Rate ≤ 85 lb CO_2/MWh	Emissions Rate ≤ 55 lb CO_2/MWh
III, IV	PUE ≤ 1.2 [30] WUE < 0.7 kWh/L [33] ERF ≥ 20% [28]	PUE ≤ 1.03 [29,31] WUE = 0 L/kWh ERF ≥ 50% [28]

Note: the definitions of these metrics have been slightly redefined to be applicable to the scale of projects under this subtopic. See below.

PUE (Power Usage Effectiveness) =

$$\frac{Energy\ used\ by\ IT\ equipment^{\dagger} + Energy\ used\ by\ other\ equipment^{\ddagger}\ (kWh)}{Energy\ used\ by\ IT\ equipment^{\dagger}\ (kWh)}$$

WUE (Water Usage Effectiveness) = $\frac{Water\ used\ by\ total\ system^{*}\ (L)}{Energy\ used\ by\ IT\ equipment^{\dagger}\ (kWh)}$

CCF (Cooling Capacity Factor) = $\frac{Cooling\ capacity\ of\ cooling\ system\ (W)}{Power\ used\ by\ IT\ equipment^{\dagger}\ (W)}$

ERF (Energy Reuse Factor) =

$$\frac{Energy\ recovered\ for\ reuse\ from\ system\ (kWh)}{Energy\ used\ by\ IT\ equipment^{\dagger} + Energy\ used\ by\ other\ equipment^{\ddagger}\ (kWh)}$$

† includes servers, switches, storage, and other similar equipment
‡ includes power used by the cooling system
* the system refers to the main IT equipment and all additional auxiliary equipment powering it

Additional Requirements:

- Submissions to this subtopic must be specifically tailored to data center applications, including at the server, system, rack, or facility level. For example, waste heat characteristics should be consistent with those of waste heat generated from data centers.

- Thermal improvements must be demonstrated, either experimentally or computationally, at a scale that is relevant for commercialization (e.g., a server rack), and must show promise of scale-up to deployment at full data centers. The system should be representative of those in modern data centers. All IT loads should be sustained at a timescale relevant to demonstrate applicability to realistic operations (e.g., 24/7 operations).
- The purpose of this subtopic is to develop and demonstrate technologies that result in meaningful improvement in data center thermal efficiency and management. As such, all improvements must be related to modern data center operations as a baseline (e.g., PUE, power density per rack, server utilization, etc.). The baseline must be reasonable and must be justified in the Full Application.
- In the Full Application, the Narrative should include a brief description of how Phase II funding would be used to advance the technology towards commercialization if selected to proceed after completion of Phase I.
- This subtopic is inclusive of novel materials and coolants (preference for nontoxic and environmentally friendly materials) as well as novel heat recovery or cooling methods and set-ups.
- Rack or server design changes may be included in the project scope but should not be the primary focus. Applicants must establish that design changes are acceptable to the industry such that they would not present a significant barrier to commercial adoption.
- Algorithmic or software innovations in controls systems for thermal management may be included in the project scope but should not be the primary focus.
- Chip-level innovations are not of interest and are not in the scope of this subtopic.

Questions – Contact: Zach Pritchard zachary.pritchard@ee.doe.gov

d. Industrial Thermal Performance Efficiency (EES)

It is estimated that approximately half of the energy input in industrial processes is lost as waste heat, emitted through hot exhaust gases, cooling water, and heat dissipation from equipment surfaces and heated products due to operational inefficiencies. A significant portion of this wasted energy is low temperature, making it challenging and often costly to recover for reuse. Efficiently recovering, and further upgrading this low-grade waste heat for utilization presents a substantial opportunity to improve energy efficiency, reduce reliance on external energy sources, and support carbon reduction goals. This subtopic will contribute toward the goal of DOE's Industrial Heat Shot: to develop a cost-competitive portfolio of industrial heat decarbonization technologies with at least 85% lower GHG emissions by 2035. This subtopic will focus on two areas of interest regarding capture and utilization of low-grade waste heat.

The first area of interest deals with the special attention that is needed for low-temperature, moisture-laden exhausts, where latent heat can account for up to 90% of the total energy. This area of interest seeks innovative concepts, designs, and solutions that significantly advance industrial thermal technologies by improving the recovery and reuse of latent heat energy in exhaust streams with high moisture content. Proposed solutions should focus on capturing low-temperature waste heat and reintegrating it into industrial processes.

The second area of interest envelops the upgrading and utilization of captured low-grade waste heat while integrating with existing thermal storage and renewable energy systems. The intent of this area of interest is to realize concepts and configurations to deliver low-cost, reliable and high-quality industrial heat source or industrial heat substitution using active thermal management while maximizing utilization of available low-grade heat, ultimately boosting process efficiency and reducing greenhouse gas emissions.

Examples of interest for the first area of interest include, but are not limited to, low-cost latent heat recuperators, advanced cooling and refrigeration technologies. Examples of interest for the second area of interest include, but are not limited to, upgrading waste-heat through integrated systems such as heat pumps and energy storage systems, reliable high-grade heat from low-grade heat sources. The integration can be achieved through either thermal or electrical renewable sources. Additionally, innovative control systems for optimizing the integration of renewable energy and energy storage into industrial processes are of particular interest.

Proposed solutions should focus on achieving substantial energy savings, reducing carbon emissions, and demonstrating scalability across a range of industrial applications.

Proposed technologies should meet the following targets:
For Area of Interest 1

- Latent heat recovery rate: At least 75% of available latent heat from exhaust streams.
- Total heat recovery: At least 90% of available total heat from exhaust streams with less than 40% moisture content by weight.
- Cost-effectiveness: At least $0.03/kWh of latent heat recovered.

For Area of Interest 2

- Upgrading low-temperature waste heat to >250°C
- Utilization rate of recovered waste heat >90%
- Cost-effectiveness: At least $0.03/kWh for waste heat recovered.

Out of Scope: For the first area of interest, technologies focused solely on sensible (dry) heat recovery without addressing latent heat are not of interest for this subtopic. For the second area of interest, development of only heat pump technology or components, chillers, fuel switching, development of only thermal energy storage technology, are not of interest for this subtopic.

Questions – Contact: Serguei Zelepouga serguei.zelepouga@ee.doe.gov

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C60-10. JOINT IEDO/BETO EES TOPIC: ENERGY EFFICIENT AQUEOUS SEPARATION 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

This topic will be providing feedback to responsive Letters of Intent.

The objective of this topic on Energy Efficient Aqueous Separation Technologies is to improve efficiency, decarbonization, and/or electrification in separation processes which enable the carbon-efficient conversion of renewable and alternative feedstocks (biogenic sources, municipal solid waste, industrial waste gas, etc.) into value added chemicals.

This joint topic is a collaboration between DOE’s Industrial Efficiency and Decarbonization Office (IEDO) and Bioenergy Technologies Office (BETO) in support of the DOE Energy Earthshot for Clean Fuels & Products. Carbon-based chemicals play pivotal roles in modern daily life and society, helping to meet the consumer product needs of the country. The scale of decarbonization effort to achieve the U.S. goals towards a “net zero” carbon economy requires a multi-faceted approach, which targets diverse sets of feedstock resources that can be transformed by a range of conversion technologies to produce the chemicals and other products needed to maintain our society. The overall objective of the Clean Fuels and Products Shot is to decarbonize the fuel and chemical industries by developing cost-effective technologies to meet a significant portion of projected demand with sustainable sources of carbon.

The Industrial Efficiency and Decarbonization Office (IEDO) leads DOE/EERE research, development, and demonstration efforts to significantly improve energy efficiency and reduce greenhouse gas emissions across industrial sectors and reach net zero carbon emissions nationwide by 2050 [1]. IEDO focuses on emerging industrial technologies, pilot-demonstrations, and technology partnerships to drive U.S. industrial decarbonization, productivity, and economic competitiveness. This topic reflects DOE's support for activities that address decarbonization in energy- and emissions-intensive industries, cross-sector industrial emissions technologies, as well as technical assistance and partnerships.

The Bioenergy Technologies Office (BETO) advances technologies that convert domestic biomass and other waste resources into cost effective, low-carbon fuels and chemicals. 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. 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.

Thermally driven separations account for 40% of the energy consumption of top industrial chemicals [2]. To encourage widespread adoption of renewable feedstocks and alternative carbon sources that lead to decarbonization across the chemical industry, there is a need to advance carbon-efficient processes for downstream separations. As processes utilizing alternative feedstocks often involve significantly more water than equivalent fossil pathways, attention must be paid to efficient organic/water separations to make alternative feedstocks both energetically and economically feasible. For example, both fermentation and electrochemical reduction of CO_2 occur in dilute aqueous media. Therefore, new technologies and approaches are needed to efficiently separate value-added products from aqueous process streams and to remove potential contaminants or poisons from product streams.

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; and
- 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.
- Describe anticipated next steps, scale up, and validation procedures assuming successful completion of Phase I objectives.

a. Unit Operations for Efficient Recovery of Value-Added Chemicals

As technologies for producing commercial chemicals from renewable resources expand, the need for energy efficient and economical dewatering techniques will grow to match. Today, much of the industry relies on distillation or other evaporative techniques to generate high purity product streams. For example, azeotropic distillation is used to separate ethanol from fermentation broth [1]. Other options such as membrane separation, pervaporation, liquid-liquid extraction, and counter-current chromatography have also been explored for other bioproducts. To meet energy efficiency and decarbonization goals, careful and accurate accounting of the energy demands of each of these techniques on real process streams is required [3]. This subtopic area seeks efficient separation processes for dilute aqueous mixtures derived from renewable and alternative feedstocks (biogenic sources, municipal solid waste, industrial waste gas, etc.) that can demonstrate substantial energy savings compared to the current commercial state of the art without increasing the total emissions footprint of the process (kg CO_2e / kg product). Processes that focus on pharmaceutical development or any product with a potential national market volume smaller than 0.5 MMT per year are out of the scope of this subtopic.

Requirements	Targets	Reference
Energy Demand (kWh / kg product; <u>if commercially available incumbent technology exists</u>)	<50%	Unit Operation vs State-of-the-Art Separation Technology
Non-Energy Emissions (kg CO_2e / kg product)	Parity or better	Onsite Process Emissions vs Incumbent Process
Preliminary Cradle to Gate GHG Emissions Analysis (kg CO_2e / kg product)	<50%	Life Cycle Emissions of Targeted Application vs Fossil Baseline
Technoeconomic Analysis ($ / kg product)	<120%	Recent Average Bulk Price
Process Output Purity	Applicant to Define Industrially Relevant Target	Dependent on Process Needs

Questions – Contact: Barclay Satterfield, may.satterfield@ee.doe.gov, Industrial Efficiency and Decarbonization Office

b. Reducing Contaminants in Product Streams

Conversion processes for renewable chemicals are challenged by contaminants present in realistic feedstocks and materials. For example, technologies targeting conversion of industrial waste gases often face conversion and safety challenges related to composition fluctuations and impurities. Many renewable chemicals may be produced via fermentation and distillation, but fermentation broth and cell lysate will contain several potential contaminants such as metals, thiols, nitrates, phosphates, amino acids, unreacted sugars, lipids, proteins, and waste biomass. These contaminants can impact product purity, poison downstream processing catalysts, foul equipment, cause safety concerns during scale-up, or release harmful emissions when burned [5]. The widespread adoption of alternative feedstocks requires cost-effective strategies to efficiently separate, and potentially valorize or recycle, these contaminants. This subtopic area seeks technologies and approaches that will enable conversion of alternative feedstocks via the removal of contaminants, undesired byproducts, or unconverted reactants. This separation may be done on either the dilute aqueous stream or the concentrated product stream depending on the needs of the application and may include technologies such as advanced continuous filtering, membranes, extractions, or adsorbents. The intent is to identify and mitigate problematic species that are detrimental to processing or that prevent the product from reaching purity requirements for downstream applications. Projects that recycle or valorize the resulting waste stream are encouraged. Processes that focus on seed oils, unprocessed biomass, or food waste oils/fats/greases are out of the scope of this subtopic.

Requirements	Targets	Reference
Energy Demand (kWh / kg product)	<80%	Unit Operation vs State-of-the-Art Separation Technology
Preliminary Cradle-to-Gate GHG Emissions Analysis (kg CO_2e / kg product)	<50%	Life Cycle Emissions of Targeted Application vs Fossil Baseline
Product Purity	Applicant Defined	Dependent on Process Needs

Questions – Contact: Barclay Satterfield, may.satterfield@ee.doe.gov, Industrial Efficiency and Decarbonization Office; Maxim Kostylev, maxim.kostylev@ee.doe.gov

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C60-11. 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 technologies has been continuously increasing. In 2014, approximately 0.7% of the total U.S. electricity generation came from solar energy; in 2022 this fraction was 4.7% and in 2023 it increased to 5.6% surpassing 5% for the first time. In California, solar accounts for more than 28% of all electricity generated, with 22 states generating more than 5% of their electricity 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. Solar PV prices have declined by 43% over the past 10 years [4]. These low costs have driven the deployment of over 137 gigawatts alternating current (GWac) of solar cumulative capacity in the United States as of the end of 2023. Approximately 26.3 GWac of PV were installed in 2023. In 2023, PV represented approximately 54% of new U.S. electric generation capacity, compared to 6% in 2010, surpassing any other power generation technology. [3]

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 [5]. SETO uses the SBIR/STTR program [6] to encourage U.S. small businesses to engage in high-risk, innovative research and technology development with the potential for future commercialization and to support transition of technologies from research institutions to the industry. Other programs include the American-Made Solar Prize [7], the Solar Manufacturing Incubator Funding Opportunity Announcements [8-10], and the Technology Commercialization Fund [11]. For more information, please review SETO's Manufacturing and Competitiveness webpage [5] and SETO's open funding opportunities [12] 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.

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 notice of funding opportunity, are eligible and encouraged to apply to both programs, if they would like to do so.

For this topic, brief feedback will be provided to applicants for both nonresponsive and responsive letters of intent.

<u>Application Guidelines</u>
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 technologies;
- 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;
- Include a clear assessment of the potential for domestic development and manufacturing;
- Demonstrate a clear and direct impact to the solar industry and have a solar application or product as an end goal;
- Be innovative and demonstrate improvements to the current state of the art, clearly describing what their novelties and advantages are compared to the current state of the industry and research in their field.

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 subsequent 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.

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 topic is not intended for creating a product, organization, service, or other entity or item that requires continued government support. Descriptions of SBIR/STTR awards made under the solar energy technologies topic can be found on the SETO SBIR/STTR webpage [6]. Information on the broader SETO research areas of interest and award portfolio can be found on the 2024 SETO Peer Review webpage [14] and the SETO solar energy research database [15].

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	Count. 30 realistic and anonymized candidate distribution circuit models identified, of which at least 20 are	Description of circuit models, load models, impedances, and connectivity characteristics	Load models, impedances, and connectivity characteristics must be included in the report to

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**
			suitable for testing	suitable for detailed testing.	included in the progress / final report submitted to DOE according to the FARC.	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 opportunity announcement.
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	Power flows validated on a single realistic	Quantitative simulation results	5% agreement is required to assess the

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**
			simulation	distribution feeder in simulation. Phasor tracking shows agreement with expected power flows at every circuit node to better than 5%.	included in the progress / final report submitted to DOE according to the FARC.	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. Innovative 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 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 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, deliver on-demand energy and power capacity, and improve reliability and resilience. Systems 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.
- Innovative methodologies and systems for health monitoring and diagnostics of solar inverters/converters that could preemptively detect and identify failures and minimize their impacts resulting in more reliable solar inverter/converter operation.

Areas not of interest:

- Products focusing on improving maximum power-point tracking as their main emphasis.
- General manufacturing of power semiconductor devices

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 will be considered nonresponsive and declined without external merit review if

- they focus on one or more areas not of interest;
- 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;

- their emphasis is not power electronic technologies and products specifically designed for solar applications;
- they focus on general manufacturing of power semiconductor devices.

The solar energy technologies topic has included a subtopic on solar power electronics in the past few years of the DOE SBIR/STTR program. A list of previous awards can be found on the SETO SBIR/STTR webpage [7]. SETO has also supported research and development of power electronics technologies through various other programs [8-9].

Questions – contact solar.sbir@ee.doe.gov

b. Dual-Use Photovoltaic Technologies

This subtopic seeks applications to advance the designs, components, and commercial maturity of dual-use photovoltaic (PV) technologies. Dual-use PV technologies are PV applications where the PV systems serve additional functions besides the generation of electricity. Dual-use PV applications of interest for this subtopic include agrivoltaics (APV), building-integrated PV (BIPV), floating PV (FPV), photovoltaic-thermal (PVT) systems, and vehicle-integrated PV (VIPV) [1]:

This subtopic solicits proposals in the five specific areas mentioned above and detailed below:

Agrivoltaics refers to the co-location of electricity and agricultural production, such as crop or livestock production or pollinator habitats. PV panels are installed on farmlands in a way that agricultural activities can continue, with agricultural production taking place underneath and/or around solar panels. [2] Agrivoltaic systems enable farmers, ranchers, and other agricultural enterprises to gain value from solar technologies while preserving land for agricultural purposes. They can be used in both open-field agriculture, in the form of solar arrays above crops or livestock or arrays with spacing in-between them where crops can grow or livestock can live, as well as in controlled-climate agriculture, at greenhouses that use sunlight (not indoor farming with artificial light). Agrivoltaics can also include solutions for the urban setting. Technologies on solar for grazing lands are of particular interest for this subtopic.

Areas not of interest in APV:

- Any solutions where the PV is on building rooftops.
- Products that involve quantum dots and tube PV.
- Proposals exclusively related to pollinator habitats.

Building-integrated photovoltaics are multifunctional construction materials. They are an integral component of the building envelope as well as a solar electric energy system that generates electricity for the building. BIPV exist in various forms and types integrating solar panels on roofing products, building facades, curtain walls, fences, canopies, carports, shade structures, spandrels, or balcony balustrades [3-6]. This area of interest also includes more general infrastructure-integrated photovoltaics, where PV systems are integrated into non-building infrastructure systems like highway sound barriers.

Areas not of interest in BIPV:

- Solar glass window products.
- Solar roadways or pavement-integrated products.

Floating photovoltaic systems are an emerging technology in which a PV system is placed directly on top of a body of water, as opposed to on land or on building rooftops. This technology, also referred to as floatovoltaics, can provide additional co-benefits to generating electricity, such as elimination of competition for land use, which could be used for other purposes, and mitigation of evaporation losses. FPV systems can be installed over natural or human-made water bodies, like lakes, freshwater reservoirs, wastewater ponds, or hydropower reservoirs. [7] This area of interest also includes systems built above bodies of water, such as canals or flooded/marshy land.
Areas not of interest in FPV:

- Products or technologies with sole application to offshore and oceanic environments.

Photovoltaic-thermal systems convert incoming solar radiation into both thermal and electrical energy. By producing two usable types of energy within the same collector, PVT can be more efficient than either PV or solar-thermal alone. The electricity produced can be pushed onto the grid, while the heat can be used for conditioning of building space, hot water, or industrial processes. [8] This area focuses on integrated PVT systems and components for PVT systems, including solar modules, collectors, and control systems.

Areas not of interest in PVT:

- Technologies that do not co-generate or aid in the co-generation of thermal and electrical energy for dual use.

Vehicle-integrated photovoltaics integrate the mechanical, electrical and design-technical aspects of photovoltaic cells or modules into vehicles. The photovoltaic devices integrate seamlessly into the vehicle structure and electric system

architecture to supply energy to on-board electric loads or batteries. VIPV devices serve dual functionality by generating electric energy while replacing other structural parts of the vehicle, like the roof, hood, doors, windows, windshield, sunroof, or other components. In simpler cases, referred to as vehicle-added or attached PV (VAPV), more traditional individual PV modules are attached to the existing vehicle structure and serve only the energy generation role. [9-11]
Areas not of interest in VIPV:
Recreational vehicles with added standard PV modules.
Products or technologies that incorporate PV modules (e.g., standard PV modules with glass front sheets) not designed or tested for vehicle applications.
Products and technologies for non-road vehicle applications (e.g., trains, marine vessels, aerial vehicles, or space vehicles).
Products and technologies for personal mobility applications (e.g., scooters or bicycles).

Applications will be considered nonresponsive and declined without external merit review if

- they focus on one or more areas not of interest;
- they do not have a clear, direct, and immediate relevance and impact to the solar industry;
- they do not fall within one of the five areas of dual-use PV described above.

SETO has supported dual-use photovoltaic technologies in the past either via the SBIR/STTR program [12] or via other programs and funding opportunities [13-14].

Questions – contact solar.sbir@ee.doe.gov

c. Technologies Enabling Solar-Powered DC Microgrids

Microgrids could play an important role in the deployment of distributed energy resources, like distributed photovoltaic systems, and in improving grid reliability and resiliency. Microgrids typically consist of loads and distributed generation assets that are connected via a small-scale grid and are controlled as a single entity with respect to the rest of the electricity grid. Alternating-current (ac) microgrids are the typical configuration, However, the concept of direct-current (dc) microgrids has been gaining interest as there are certain applications that are better aligned with and could benefit from dc microgrids. These could also involve dc distribution systems and nanogrid within buildings, which could directly connect dc energy sources (e.g. on-site PV generation and dc-coupled energy storage) and serve dc loads (e.g. LED lighting, computers and electronics, electric vehicle charging, HVAC and water heating systems with variable frequency drives) directly from a dc bus. Broader adoption and deployment of such dc microgrids will critically depend on a compelling value proposition, technical advancement in modeling, operation, and control technologies, commercial availability, and standardization of dc equipment and appliances, as well as development of appropriate reliability and safety standards.

This subtopic seeks applications to advance the components, design, and commercial maturity of dc microgrids incorporating solar energy resources, dc loads, and potentially dc-coupled energy storage.

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

- Innovative designs and architectures of dc microgrid and building nanogrids.
- Tools for planning, design, and quantification of benefits of dc microgrids.
- Power electronic for dc bus architectures including solar PV.
- Local controllers and energy management systems for the operation of dc microgrids.
- Local and wide-area control systems for the operation of multiple interconnected dc microgrids with multiple distributed energy resources.
- Modeling and simulation of dc systems and microgrids, including operation, control, and stability analysis.
- Systems for fault detection, protection, and dc circuit breaker hardware.

Areas not of interest for this subtopic:

- Development of dc appliances.
- Converters and power electronics not designed and intended for dc microgrid operation.
- Technologies and products for ac microgrids.

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d. Cybersecurity of Solar Energy Systems (DOE Crosscuts: Grid Modernization, Energy Sector Cybersecurity)

Ensuring reliable and safe operation of electrical grids is critical for the U.S. economy and national security. Cybersecurity of the electricity grid is regarded as the protection of interconnected electric power systems from digital attacks. As the amount of solar energy on the grid grows, solar has become as an integral part of the system, contributing to large-scale generation, as well as small-scale distributed energy resource (DER) generation in the form of rooftop installations, storage systems, and microgrids, which typically are spread out over a wide area. Unlike large-scale generation systems that must be compliant to critical infrastructure protection standards before they can be operational, smaller PV systems and other DERs currently do not have any cybersecurity standards to follow, and they are usually connected by their owners to necessary networks for monitoring and control purposes. The electric grid is a cyber-physical system, thus cyberattacks on the grid can cause physical damage and safety issues in addition to disrupting information flow. Growing deployment of DER networks in electric grid led to a rise in the attack surface against these systems, and result in higher vulnerabilities in the grid that hackers can exploit, making DER cybersecurity a key challenge for grid operators and solar system owners.

Improving cybersecurity in renewable energy is part of DOE Energy Efficiency and Renewable Energy (EERE) Office's Multi-Year Program Plan [1], and also supports SETO's goals of reliably and securely integrating solar electricity into the grid [2]. In 2022, the Office of EERE along with the Office of Cybersecurity, Energy Security, and Emergency Response (CESER), developed the Cybersecurity Considerations for DER on the U.S. Electric Grid report [3], which provides recommendations for the DER industries, energy sector, and government to secure current and future systems. Over the past decade, SETO has funded various research and development programs [4-8] that aim to understand the evolving characteristics of cyberattacks, advance cybersecurity technologies to protect electric grids from cyberattacks, and develop cybersecurity standards and certifications.

This subtopic seeks to advance technologies and products to enable more cyber-aware and cyber-secure electric power systems with high penetration of solar (particularly in the form of distributed deployment) and to improve the ability of electric grids and solar assets, like solar/hybrid power plants and their components (e.g., electronic devices associated with solar energy systems, such as inverters, dc-dc optimizers or other converters, smart meters, and grid-edge devices) to protect themselves from and quickly recover in response to cyber threats.

Specific areas of interest include, but not limited to:

- Innovative cyberattack detection and identification schemes that can be applied across various solar assets, from distributed customer devices to utility-scale systems.
- Tools that perform risk assessments that recognize the increasing interdependencies between physical and cyber (information and communication) systems and evaluate how cyberattacks can affect electric power grid operations.
- Automated risk-mitigation strategies that allow rapid response and service restoration of electric grid and solar assets after cyber-attacks and demonstrate the system ability to endure multiple simultaneous attacks.
- Device-level cybersecurity and protection systems that enable self-awareness into the grid-interactive solar assets.
- Controls and operations of solar assets that are designed and can be deployed adhering with zero trust principles where data and commands from remote devices are validated using cryptographically secure mechanisms (e.g., the capability to reject a setpoint/commands and take corrective actions if the estimated risk factor is high enough to cause instability and abnormal operations).

- System-level cyber threat detection, identification and mitigation approaches via cooperative strategies among large amounts of geographically dispersed solar assets, other DERs, and sensors based on either centralized or distributed communication networks.

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e. Distribution Reliability Visibility (DOE Crosscuts: Grid Modernization)

The increased adoption of distributed solar and other energy resources (DERs) can impact the performance of distribution system if not properly managed and challenge the reliable operation of distribution grids. The impacts (e.g., overvoltage and thermal violations, miscoordination and misoperation of protection devices, faster dynamics, uncertain, and potential adverse control interactions of inverter-based resources, etc.) are exacerbated by a lack of operator situational awareness of distribution grids, particularly the assets and systems at the grid-edge and even behind-the-meter. SETO tries to address solar energy system integration challenges [1] and has funded multiple research, development and deployment programs to understand the behavior of grids with high contributions from DER and inverter-based resources through various funding opportunities [2-7]. These programs have aimed to understand the fundamental needs of sensors and measurements and advance technologies that enhance the visibility and controllability of distribution grids with high penetration of solar and other DERs.

This subtopic seeks to advance technologies and products to enhance the visibility of distribution grids and provide actionable information for grid operators to safely and reliably operate the distribution system.

Specific areas of interest include, but not limited to:

- Advanced voltage monitoring and analysis systems that can
  - estimate the spatial and temporal voltage profiles of distribution feeders in real-time by considering the intermittency and uncertainty of solar energy resources;
  - detect the 'hotspot' node voltages exceeding safe operational limits;
  - facilitate voltage stability margin and hosting capacity estimation and analysis; and
  - enable optimal voltage control via inverter-based DERs and other grid-edge devices.

The proposed solutions must also be computationally efficient to be suitable for real-time applications.

- Advanced distribution state estimation techniques that can address the complications inherent with distribution grids (e.g., time-varying unbalance, limited availability of real-time measurements, asynchronous and/or heterogenous measurements from different sensing/metering infrastructures, incorrectly captured and/or time-varying network connectivity and topology, etc.). The proposed solutions must also be computationally efficient to be suitable for real-time applications.
- Innovative technologies that can estimate and predict dynamic operating envelopes and reserve margins (generally defined as time-varying upper and lower bounds on the import or export of power in a given time interval) of DERs at various aggregation levels of connection points (e.g., service entry point,

feeder, substation level, or subdivision of a distribution system). The developed solutions are expected to support distribution operation in real-/near-real-time, increase the utilization of DERs and assist DERs to participate in energy and network services markets.

- Innovative technologies that support dynamic hosting capacity estimate for utilities to better strategize for distribution system upgrades. The developed solutions are expected to incorporate, besides siting considerations of DERs, autonomous inverter functions (e.g. volt-var control), and/or optimal coordinated control of DER at various aggregate levels.
- Innovative technologies that identify emerging risks and unstable system dynamics in real time and predict future behaviors. The developed solutions are expected to ingest large amounts of data captured by dispersed sensors and monitoring devices with various resolutions and sources, such as wide-area phasor measurement units, substation intelligent electronic devices, devices capable of streaming point-on-wave data, power quality meters, and digital fault recorders and relays, and energy management systems. The solutions are also expected to provide automatic event analysis, reporting, and recommendations for reliability risk mitigation.
- Grid-Edge intelligent analytics and devices that can improve distribution system's situational awareness, assist DER aggregation and support automated control and operation of distribution grids. The developed solutions are expected to host advanced real-time analytics and optimization (example applications listed above), and support flexible and open communication and control architectures (e.g., the cloud/utility premises; centralized/decentralized/distributed) for interoperable integration to a utility distributed energy resource management systems (DERMS) or advanced distribution management systems (ADMS), a third party aggregator DERMS, and behind-the-meter (BTM) assets and resources.

Areas not of interest:

- Solutions that primarily focus on health monitoring and diagnostic of individual grid components and assets.

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

While PV has dominated the U.S. solar market, with over 137 GW deployed cumulatively by the end of 2023 [1], CSP technologies offer a unique value as a renewable energy resource that can readily deliver high-temperature heat and incorporate storage for on-demand energy. There are nearly 100 CSP plants in commercial operation worldwide, representing almost 7 GW of capacity. Existing CSP plants have demonstrated long durations of thermal energy storage (TES), up to 15 hours, which increases their value to the grid. With integrated TES, CSP plants can produce 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 [2].

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 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-temperature heat 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 [3]. This represents, approximately, a 50% reduction of existing costs. Although this target is aggressive, there are multiple pathways by which it may be achieved. [4]. The primary technical strategy towards this cost target 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 (Gen3 CSP) [5] 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). An advanced power cycle, such as the sCO_2 Brayton cycle can be used to convert the high temperature heat to electricity. In March 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 (see announcement here). Testing on the facility is anticipated to begin in 2025.

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, sCO_2 power cycles, 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 [6], has identified potential areas of improvement with respect to reliability of operating CSP plants. The areas of interest include development of high-impact components that historically have suffered from reliability problems. Innovations that increase the operability, decrease operations and maintenance costs, or decrease plant installation costs of commercial CSP plants are also of interest.

Beyond CSP for electricity, SETO works to make solar industrial process heat (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 include 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.

For more information about recent CSP funding opportunities and selections, click on the following links:
American-Made Challenges: Solar Desalination Prize
American-Made Heliostat Prize
SETO Small Innovative Projects in Solar 2023: Concentrating Solar-Thermal Power and Photovoltaics Funding Program
FY23 Solar-thermal Fuels and Thermal Energy Storage Via Concentrated Solar-thermal Energy Funding Program
FY24 Concentrating Solar Flux to Heat and Power Funding Opportunity
Fiscal Year 2024 Small Innovative Projects in Solar (SIPS): Concentrating Solar-Thermal Power and Photovoltaics Funding Program

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g. Affordability, Reliability, Performance, and Manufacturing of Solar Systems

This subtopic solicits proposals for technologies that can advance solar energy by lowering cost and facilitate the secure integration into the Nation’s energy grid. Applications must fall within one of these areas: solar system integration in the electricity grid, concentrating solar-thermal power technologies, or photovoltaic technologies. As noted above, descriptions of previous SBIR/STTR awards made under the solar energy technologies topic can be found on the SETO SBIR/STTR webpage [6]. Broader information on SETO research areas of interest and award portfolio can be found on the 2024 SETO Peer Review webpage [14] and the SETO solar energy research database [15].

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

- Technologies that reduce the manufacturing costs of solar energy system components or subcomponents to boost domestic energy manufacturing and increase U.S. manufacturing competitiveness.
- Technologies that can measure, validate, or increase outdoor PV system reliability.
- Technologies that improve operation and maintenance of PV systems. Can include self-contained smart PV systems with sensors that detect actual or imminent power loss, or mobile instrumentation for low-cost field diagnostics.
- Technologies enhancing the ability of solar energy systems to contribute to grid reliability, resiliency, and security.
- Technologies that reduce the structural and electrical balance-of-system costs of a PV system.
- Technologies that reduce the soft costs associated with the installation and operation of PV systems. 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 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 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, analysis, taxonomies, and best practices developed from these programs can be leveraged as the impetus for small business innovation.

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

Applications will be considered nonresponsive and declined without external merit review if they are not based on sound scientific principles 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 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 are within the scope of any other of the subtopics listed under the Solar Energy Technologies topics. Such applications should be submitted to the appropriate topic and subtopic and would be considered nonresponsive for this subtopic.
- Involve technologies that fall under areas not of interest or under the non-responsiveness descriptions of all other subtopics of the Solar Energy Technologies topics. Such areas are not of interest for this topic overall.
- Focus primarily on the development of software solutions.
- 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.
- Propose development of ideas or technologies that have already received federal support for the same technology at the same technology readiness level.

Questions – contact solar.sbir@ee.doe.gov

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2. U.S. Department of Energy, 2018, Solar Energy Technologies Office, *Advanced Systems Integration for Solar Technologies (ASSIST): Situational Awareness and Resilient Solutions for Critical Infrastructure | Department of Energy* (October 28, 2024)
3. U.S. Department of Energy, 2019, Solar Technologies Office, *Solar Energy Technologies Office Lab Call FY2019-21 – Systems Integration | Department of Energy* (October 28, 2024)
4. U.S. Department of Energy, 2019, DOE, *2019 Grid Modernization Lab Call Awards | Department of Energy* – Topic Area: ADVANCED SENSORS AND DATA ANALYTICS (October 28, 2024)
5. U.S. Department of Energy, 2021, Solar Energy Technologies Office, *Solar Energy Technologies Office Lab Call FY2022-24 – Systems Integration | Department of Energy* (October 28, 2024)
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1. Feldman, D., Zuboy J., Dummit K., Stright D., Heine M., Grossman S., Margolis, R., Spring 2024 Solar Industry Update, May 14, 2024, https://www.nrel.gov/docs/fy24osti/90042.pdf (October 29, 2024)
2. U.S. Department of Energy, 2023, Solar Energy Technologies Office, *US DOE, Solar Energy Technologies Office*, https://energy.gov/solar-office (October 29, 2024)
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C60-12. SOLAR ENERGY TECHNOLOGIES (STTR 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:** 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 technologies has been continuously increasing. In 2014, approximately 0.7% of the total U.S. electricity generation came from solar energy; in 2022 this fraction was 4.7% and in 2023 it increased to 5.6% surpassing 5% for the first time. In California, solar accounts for more than 28% of all electricity generated, with 22 states generating more than 5% of their electricity 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. Solar PV prices have declined by 43% over the past 10 years [4]. These low costs have driven the deployment of over 137 gigawatts alternating current (GWac) of solar cumulative capacity in the United States as of the end of 2023. Approximately 26.3 GWac of PV were installed in 2023. In 2023, PV represented approximately 54% of new U.S. electric generation capacity, compared to 6% in 2010, surpassing any other power generation technology. [3]

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 [5]. SETO uses the SBIR/STTR program [6] to encourage U.S. small businesses to engage in high-risk, innovative research and technology development with the potential for future commercialization and to support transition of technologies from research institutions to the industry. Other programs include the American-Made Solar Prize [7], the Solar

Manufacturing Incubator Funding Opportunity Announcements [8-10], and the Technology Commercialization Fund [11]. For more information, please review SETO's Manufacturing and Competitiveness webpage [5] and SETO's open funding opportunities [12] 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.

This topic is open only to STTR applications. The intent of this topic is to support technology transfer from academia, national laboratories, and other research entities to the industry, moving forward the commercialization of these technologies. Interested applicants are encouraged to partner with national laboratories and other research entities in response to this topic.

For this topic, brief feedback will be provided to applicants for both nonresponsive and responsive letters of intent.

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 technologies;
- 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;
- Include a clear assessment of the potential for domestic development and manufacturing;
- Demonstrate a clear and direct impact to the solar industry and have a solar application or product as an end goal;
- Be innovative and demonstrate improvements to the current state of the art, clearly describing what their novelties and advantages are compared to the current state of the industry and research in their field.

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 subsequent 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.

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 topic is not intended for creating a product, organization, service, or other entity or item that requires continued government support. Descriptions of SBIR/STTR awards made under the solar energy technologies topic can be found on the SETO SBIR/STTR webpage [6]. Information on the broader SETO research areas of interest and award portfolio can be found on the 2024 SETO Peer Review webpage [14] and the SETO solar energy research database [15].

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.

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**
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 opportunity announcement.
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	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.

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**
				at every circuit node to better than 5%.		
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. Innovative Software Technologies and Products for Solar Energy Systems

This subtopic seeks applications on software systems and software-enabled business models that aim at improving the performance, reliability, and affordability of solar systems by automating processes and procedures during the design, installation, and operation of such systems. Software solutions could involve, but are not limited to, system modeling, simulation, design, installation support or automation, asset performance monitoring and management, plant control and operation optimization, etc. Applications should involve innovative software systems that will increase the competitiveness of the U.S. solar industry.

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

Software products that directly or indirectly reduce costs, optimize performance, or provide a novel service or functionality at any point within the life cycle of a solar system. Software products should focus on scalability, ease of integration, user interface design, or improvement of the state of the art, when applicable.

Innovative grid modeling and simulation software incorporating novelties for the integration of inverter-based solar resources.

Innovative grid monitoring, operation, and control algorithms and software incorporating novelties for the integration of inverter-based solar resources. Innovative software for distributed energy resource management systems (DERMS) or advanced distribution management systems (ADMS) that allows for improved coordination of renewable distributed energy resources and enhanced management of distribution grids in the presence of variable energy resources.

Software facilitating the development and operation of virtual power plants (VPPs), which are a connected aggregation of distributed energy resources and loads (DERs) operated in a coordinated way. VPPs offer deeper integration of renewable energy and demand flexibility, which in turn offers cleaner and more affordable power.

Methodologies, algorithms, and software systems for the control, operation, and grid integration of DERs and VPPs are areas of great interest for this subtopic. Such solutions should have a clear focus on solar DERs and VPPs that incorporate solar systems.
High-level control software for coordinating and optimizing the operation of solar plants and fleets of solar plants, enabling dispatchability of solar resources and allowing them to provide additional functionality and services to the electricity grid.

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 or do any of the following: Revolve around software products comparable to what are already publicly available from government sources or government-funded research institutions without demonstrating significant objective improvements.

Involve duplicative software solutions with many existing competitors in the market, such as software for:

- Tracking solar system performance or data collection;
- Facilitating solar system design or general solar system monitoring;

- Designing transmission and distribution power grids with no special considerations for integration of inverter-based resources;
- Improving customer and/or business acquisition processes;
- Providing finance, tax, or monetary benefits; or
- Listing, presenting, sorting, or otherwise organizing physical locations, websites, databases, or other collections of solar industrial data without meaningful, state-of-the-art processing.
- Focus on device-level control software for the low-level operation of inverters or other power electronics devices, which would typically be part of the operating firmware of such a device.

Questions – contact solar.sbir@ee.doe.gov

SETO Topic References:

1. U.S. Department of Energy, 2024, Solar Energy Technologies Office, *US DOE, Solar Energy Technologies Office,* https://energy.gov/solar-office (October 29, 2024) U.S. Department of Energy, 2021, Solar Energy Technologies Office, Solar Futures Study, Nov. 4, 2021, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/solar-futures-study (October 29, 2024)
2. Feldman, D., Zuboy J., Dummit K., Stright D., Heine M., Grossman S., Margolis, R., Spring 2024 Solar Industry Update, May 14, 2024, https://www.nrel.gov/docs/fy24osti/90042.pdf (October 29, 2024)
3. Solar Market Insight Report, Solar Data Cheat Sheet, Solar Energy Industries Association, https://seia.org/wp-content/uploads/2024/09/Solar-Cheat-Sheet-Q3-2024.pdf (October 29, 2024)
4. U.S. Department of Energy, 2024, Solar Energy Technologies Office, Manufacturing and Competitiveness, *US DOE, Solar Energy Technologies Office,* https://www.energy.gov/eere/solar/manufacturing-and-competitiveness (October 29, 2024)
5. U.S. Department of Energy, 2024, Solar Energy Technologies Office, Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR), https://www.energy.gov/eere/solar/solar-topics-small-business-innovation-research-and-small-business-technology-transfer (October 29, 2024))
6. U.S. Department of Energy, 2024, American-Made Solar Prize, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/american-made-solar-prize (October 29, 2024)
7. U.S. Department of Energy, 2022, Solar Energy Technologies Office Fiscal Year 2022 Solar Manufacturing Incubator, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/articles/funding-notice-fiscal-year-2022-solar-manufacturing-incubator (October 29, 2024)U.S. Department of Energy, 2023, Solar Energy Technologies Office Fiscal Year 2023 Silicon Solar Manufacturing and Dual-use Photovoltaics Incubator Funding Program, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/silicon-solar-manufacturing-and-dual-use-photovoltaics-incubator-funding-program (October 29, 2024)

8. U.S. Department of Energy, 2024, Solar Energy Technologies Office Fiscal Year 2024 Solar Energy Supply Chain Incubator, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/funding-notice-solar-energy-supply-chain-incubator (October 29, 2024)U.S. Department of Energy, 2024, Technology Commercialization Fund, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/technology-commercialization-fund (October 29, 2024) U.S.Department of Energy, Solar Energy Technologies Office. https://www.energy.gov/eere/solar/funding-opportunities (October 29, 2024)
9. The American-Made Challenges, 2024, https://network.americanmadechallenges.org (October 29, 2024)
10. U.S. Department of Energy, 2024, 2024 SETO Peer Review, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/2024-seto-peer-review (October 29, 2024)
11. U.S. Department of Energy, 2024, Solar Energy Research Database, *US DOE, Solar Energy Technologies Office*, https://www.energy.gov/eere/solar/solar-energy-research-database (October 29, 2024)

C60-13. 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

Vehicles move our national economy. The Vehicle Technologies Office (VTO) leverages the unique capabilities and world-class expertise of the National Laboratory system, industry, and academia partners to improve technologies, including advanced battery technologies. Current successes include reducing the costs of producing electric vehicle batteries by more than 90% over the last 15 years, advancing materials for lighter-weight vehicle structures and improved powertrains, and providing energy-efficient mobility technologies, including automated and connected vehicles. VTO also advances innovative powertrains to reduce greenhouse gas (GHG) and criteria emissions.

Each year in the U.S., vehicles transport 18 billion tons of freight – about $55 billion worth of goods each day – and move people more than 3 trillion vehicle-miles. The transportation sector accounts for approximately 27 percent of total U.S. energy demand and over 17 percent of average U.S. household expenditures, making it, as a percentage of spending, the costliest personal expenditure after housing. Transportation is critical to the overall economy, from the movement of goods to providing access to jobs, education, and healthcare. The transportation sector has historically relied heavily on petroleum, which supports over 90 percent of the sector's energy needs today and, as a result, has surpassed electricity generation to become the largest source of CO_2 emissions in the country.

VTO funds research, development, demonstration, and deployment (RDD&D) of new, efficient, and clean vehicle and mobility solutions that are affordable for all Americans to accelerate development and deployment of new vehicle technologies and reduce greenhouse gas (GHG) emissions economy-wide. VTO's vision is economy-wide decarbonization in accordance with the U.S. National Blueprint for Transportation Decarbonization, which is a landmark strategy for cutting all transportation sector greenhouse gas emissions by 2050. VTO will continue implementing strategies to ensure the benefits of federal investments flow to disadvantaged communities in accordance with the Justice40 Initiative.

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., relevant 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
b. Improving EV Battery Recycling Efficiency (BIL-Funded)
c. Improving Consumer Electronic Battery Recycling Efficiency (BIL-Funded)
d. Modular Heavy-Duty Vehicle Batteries
e. Material Innovations for Thermal Runaway Mitigation in High-Energy Battery Enclosures
f. EV Battery Firefighting Technologies
g. Electrified Hydraulic Components for Off-road Equipment
h. Increasing Efficiency Through Systemwide Innovation

a. Innovative Electric Vehicle Battery Cells and Components

This topic seeks development of electrochemical energy storage technologies that support commercialization of electric vehicles focused on improving the state of the art for battery cells for 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. Where applicable, proposed technologies should meet all listed metrics.

Areas of Development	Topics of Interest and Performance Metrics	Not of Interest

Cathode (Li-ion)	• High energy density (Co-free, >1,000 Wh/kg at material level) • Low cost (Ni/Co-free, >800 Wh/kg, <$65/kWh at cell level or <$15/kg at material level) • Fast charge-capable (10-min fast charge for 20% to 80% SOC, 100% fast charge cycles, 3.6C minimum rate, 1,000 cycles) • Low temperature-capable (>70% capacity C/3 at -30°C and survival at -40°C)	• LFP • NMC • NCA
Sodium-Ion	• Cathode (layered oxide, polyanion) (>800 Wh/kg) • Anode (hard carbon, alloy, intercalation) (<0.2 V, >350 mAh/g) • Electrolyte (≥10 mS/cm at room temperature) • Low cost (<$65/kWh at cell level) • Li/Co-free	• Na metal anode • Low energy density (<160 Wh/kg)* • High Ni content (>30%) • Solid-state electrolytes • Prussian blue analog electrodes
Sulfur Cathode	• High sulfur content (>60% total electrode mass) • High capacity (>1,000 mAh/g) • Good cycle life (>500 cycles at C/3) • High cell energy density (>300 Wh/kg)* • Low pressure (<1 MPa)	1.
Li Metal	• High cell energy density (>350 Wh/kg)* • Cycle life >500 cycles • Thin Li (<20 um) • High loading cathode (>4 mAh/cm^2) • Lean electrolyte (<2.5 g/Ah) (for liquid electrolyte) • Thin solid-state separator (<50 um) (for solid-state electrolyte) • Low pressure (<1 MPa)	
Si anode	• 100% Si, SiO_x, SiC containing active material • Long calendar life (>10 years) • High capacity (>1200 mAh/g utilized capacity) • High energy density (>340 Wh/kg)* • Low cost (<$75/kWh cell level, <$20/kg material level) • Fast charge-capable (10-min fast charge for 20% to 80% SOC, 100% fast charge cycles, 3.6C minimum rate, 1000 cycles) • Low temperature-capable (>70% capacity C/3 at -30°C and survival at -40°C)	• Graphite blend • EC containing electrolytes
Manufacturing/ Inactive Components	• Binder (PFAS-free) • Separator (Conformal/integrated separator, PFAS-free) • Foil/cell components (lowered cost/increased energy density by at least 15% for commercial technology) • Dry electrode processing • Roll-to-roll capable	

Safety and Diagnostics	• Low-cost thermal runaway mitigation/prevention (15% cost savings with no impact on performance) • High-speed diagnostic hardware for manufacturing • Phase I deliverable should be a prototype, e.g., module with safety implementation; Phase II deliverable should be a scaled version of final product	• Pack, module, or BMS level solutions • Software only solutions

*Cell level energy density targets when scaled to automotive sizes (>20 Ah)

When appropriate, the technology should be evaluated in accordance with applicable test conditions or recommended practices as published by the Department of Energy (DOE) and the U.S. Advanced Battery Consortium (USABC). These test procedures can be found on the USABC website [1] (note: focus on test conditions rather than cycling protocols). 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 200 mAh single-layer pouch cell demonstrating 100 cycles at C/3. Phase II technologies should be evaluated in full cells ≥1 Ah capacity demonstrating 1,000 cycles at C/3. Proposed final deliverables will be evaluated based on size and feasibility compared to the state of the art for that technology.

All submissions must 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 R&D program goals and project performance can be referenced from our Annual Progress Report [2] and can provide relevant state of the art performance metrics and baselines when industry metrics are not available.

Questions – Contact: Nico Eidson, Nicolas.Eidson@ee.doe.gov and Stephanie Spence, Stephanie.Spence@ee.doe.gov

References:

1. USABC Manuals, United States Council for Automotive Research, LLC. www.uscar.org/usabc
2. Vehicle Technology Office Annual Progress Reports https://www.energy.gov/eere/vehicles/annual-progress-reports

b. Improving EV Battery Recycling Efficiency (BIL-Funded)

Commercial battery recycling is vital to meet U.S. climate change and circular economy goals and strengthen domestic supply chains of critical materials. Solving key challenges such as the high processing cost of recycling battery material requires novel R&D efforts [1,2]. This subtopic seeks innovative technologies or processes that increase the efficiency or economic viability of recycling end-of-life electric vehicle (EV) batteries. Technologies should advance the state of the art and have a clear pathway towards commercialization and competitiveness in the domestic market. Technological approaches of interest include:

- Processes that focus on feedstocks from end-of-life lithium-ion EV batteries (with a focus on NMC, NCA, or LFP chemistries)
- Direct recycling and upcycling approaches
- Hydrometallurgical approaches
- Processes that substantially decrease energy, water, reagent use, waste generation, and greenhouse gas emissions over current recycling practices
- Processes that increase lithium, cobalt and nickel recovery yield to above 90%
- Other processes that increase economic viability and yield of recycling processes to help reach 90% recovery by weight of battery materials from recycling feedstocks

Phase I efforts should focus on validation or small-scale demonstration of the proposed technology or process. The Phase I work plan should include preliminary life cycle analysis (LCA) and technoeconomic analysis (TEA) to understand how the technology or process compares to current processes. Submissions should propose a plan to achieve a processing rate of 100 tons/year with the proposed technology to demonstrate scalability. Phase II work should focus on commercialization and demonstrating that the technology is able to be integrated into the battery recycling ecosystem. All submissions should clearly explain how the proposed work differs from other work in the field and should not be duplicative of ongoing projects.

Questions – Contact: Stephanie Spence, Stephanie.Spence@ee.doe.gov, Jake Herb, Jake.Herb@ee.doe.gov, and Tina Chen, Tina.Chen@ee.doe.gov

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c. Improving Consumer Electronic Battery Recycling Efficiency (BIL-Funded

Commercial battery recycling is vital to meet U.S. climate change and circular economy goals and strengthen domestic supply chains of critical materials. Solving key challenges such as the high processing cost of recycling battery material requires novel R&D efforts. This subtopic seeks innovative technologies or processes that increase the efficiency or economic viability of recycling end-of-life consumer electronic batteries. Technologies should advance the state of the art and have a clear pathway towards commercialization and competitiveness in the domestic market. Technological approaches of interest include:

- Processes that focus on secondary battery feedstocks from consumer electronics or e-waste (devices <300 Wh and <11 pounds, with a focus on LCO and LFP chemistries).
- Hydrometallurgical approaches that make Co available to feed into NMC production.

- Approaches that upcycle LCO to NMC.
- Approaches that demonstrate value-positive recovery of materials for LFP-based batteries.
- Processes that substantially decrease energy, water, reagent use, waste generation, and greenhouse gas emissions over current recycling practices.
- Processes that increase lithium and cobalt recovery yield to above 90%.
- Other processes that increase economic viability and yield of recycling processes to help reach 90% recovery by weight of battery materials from recycling feedstocks.

Phase I efforts should focus on validation or small-scale demonstration of the proposed technology or process. The Phase I work plan should include preliminary life cycle analysis (LCA) and technoeconomic analysis (TEA) to understand how the technology or process compares to current processes. Submissions should propose a plan to achieve a processing rate of 100 tons/year with the proposed technology to demonstrate scalability. Phase II work should focus on commercialization and demonstrating that the technology is able to be integrated into the battery recycling ecosystem. All submissions should clearly explain how the proposed work differs from other work in the field and should not be duplicative of ongoing projects.

Questions – Contact: Stephanie Spence, Stephanie.Spence@ee.doe.gov, Jake Herb, Jake.Herb@ee.doe.gov, and Tina Chen, Tina.Chen@ee.doe.gov

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2. Argonne National Laboratory, 2024, “Bridging the U.S. Lithium Battery Supply Chain Gap: Forum on Li-ion Battery Recycling and End-of-Life Batteries.” (2024) https://www.anl.gov/access/reference/bridging-the-us-lithium-battery-supply-chain-gap-forum-on-liion-battery-recycling-and-endoflife (October 29, 2024)

d. Modular Heavy-Duty Vehicle Batteries

Medium- and heavy-duty vehicles make up 5% of the on-road fleet but contribute 21% of transportation emissions [1]. A subset of 10% of heavy-duty vehicles with high utilization are responsible for 50% of emissions from this sector [1]. A Class 8 electric truck needs at least 1 MWh of energy on board for it to travel 500 miles on a single charge [2], and Class 7/8 buses may require at least 500 kWh energy on board, depending on duty cycle [3]. The weight and volume of Li-ion batteries needed to achieve long-distance travel in these heavy-duty vehicles raises the prospect of offsetting cargo or passengers, which is not acceptable to end users. Furthermore, it requires high-power charging (1 MW+) to keep charging times reasonable for these large battery packs.

This topic considers designs for two possible alternatives to accelerate electrification of the heavy-duty vehicle sector while working with the energy density limitations of

currently available Li-ion batteries and charging infrastructure: 1) offsetting megawatt charging needs and minimizing wait times at truck charging stops through battery swapping (Class 8 trucks and Class 7/8 buses), and 2) additional on-board energy storage to increase range by enabling batteries in trailers (Class 8 trucks only).
Smaller, easily replaced “swappable” batteries present an alternative to long charging times or the need for widespread megawatt charger deployment. Trucks come in different designs with various spaces available for batteries, and this modular battery approach could help realize range extension with minimal waiting, reduce infrastructure needs and grid demand at charging by enabling flexible charging of battery packs off-peak and at lower power.

Another alternative is battery storage on trailers. Some refrigerated trucks, which require a power source operating independently of the truck, already demonstrate such battery storage. This topic seeks designs that use the batteries on the trailer for vehicle propulsion/range extension rather than auxiliary power for refrigeration only. Trailer batteries should provide energy for propulsion of the truck tractor, and could also include trailer propulsion through electric axles.

Requirements:

Phase I: At the end of the Phase I project, deliver a conceptual system design focused on the battery pack, including battery-vehicle interface, and demonstrating all relevant requirements, including but not limited to: specifying system size, energy density, specific energy, and expected vehicle range and assessing system design for safety and durability criteria such as crash safety, ruggedness, mitigation of water and dirt intrusion, and corrosion, among others.

Advantages over conventional battery packs and over diesel ICE truck designs should be clearly stated, including cost, range, downtime for fueling/charging/battery replacement based on preliminary analysis.
Phase I work that incorporates development through design and testing with a heavy-duty OEM is preferred.

Phase II: At the end of Phase II, deliver a full system design demonstrating all key components, including the pack or module(s) and the full vehicle powertrain and simulation of performance. Applicants must specify component-level, vehicle system-level, and freight system-level technologies including overall vehicle design and projections of expected performance, including vehicle range based on battery pack capacity, lifetime, cost, provisions for battery state of health monitoring, and other relevant figures. The data and tools used for any simulation of system level benefits should be clearly identified and should be up to date. The Phase II project must also deliver a technoeconomic analysis including total cost of ownership for the planned system. Commercialization plans should address near-term vehicle demonstration, truck and battery ownership models, battery storage and charging, and opportunities for market entry.

For proposals based on battery storage in trailers, the system must contribute to and interface with the truck's powertrain, and batteries must be used for propulsion rather than as auxiliary power.

Letters of support from HD truck or bus OEMs are encouraged.

Hybrid architectures (ICE or FCEV) are not of interest for this topic, but designs in which some batteries are fixed to the vehicle while others are swappable to provide range extension are acceptable.

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

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1. DOE, 2022, The U.S. National Blueprint for Transportation Decarbonization (2022) p. 61-63. https://www.energy.gov/sites/default/files/2023-01/the-us-national-blueprint-for-transportation-decarbonization.pdf (October 29, 2024)
2. 21st Century Truck Partnership Electrification Technical Sector Team Roadmap (2023) https://www.energy.gov/sites/default/files/2023-12/21CTP-ETT-Roadmap_Final_Sep2023_compliant_corrected_08Dec23.pdf (October 29, 2024)
3. DOT, 2023, U.S. Department of Transportation Electric Bus Basics,https://www.transportation.gov/rural/electric-vehicles/ev-toolkit/electric-bus-basics (October 29, 2024)

e. Material Innovations for Thermal Runaway Mitigation in High-Energy Battery Enclosures

In today's rapidly developing electric vehicle (EV) industry, thermal management[1] to preserve battery health has become a key factor in determining the performance and safety of EVs. As cell energy density continues to advance, battery systems are becoming increasingly complex, making thermal management more challenging. The issue of EV battery safety, especially preventing thermal runaway[2-3], motivates exploration of effective fire prevention and early-detection solutions. Thermal runaway, mechanical damage, manufacturing defects, and external impact can cause EV battery fires[4].

When a battery cell undergoes thermal runaway, it releases intense heat and toxic gases, and can potentially lead to explosions or fires. Early detection of electrical vehicle fires and prevention of cascading thermal runaway are critical to mitigate the risks associated with these incidents. Pouch, prismatic, and cylindrical cell formats are used in EVs, and each requires unique inter-cell materials to protect against heat and fire. For example, prismatic layouts typically use materials in sheet format, such as mica[5-6]. It is imperative to thoroughly understand and develop optimal materials strategies to reduce the likelihood of cascading effects from EV fires as a cost-effective means to increase EV safety.

Objective

The objective of this topic is to develop advanced materials technologies and efficient fire-prevention strategies to prevent and/or reduce the likelihood of the cascading effects of EV fires while minimizing mass and cost. Thermal runaway failures on cells, unless controlled, could propagate to the surrounding cells, modules/packs of EV batteries and could propagate to vehicle level or even surrounding vehicles in a garage. Comprehensive research is needed to enhance battery safety against cascading failures, from the cell level up to the battery pack. Of particular interest are improvements in safety for high-energy EV Li-ion batteries by preventing cell-to-cell and module-to-module thermal transport and cell failure propagation. Beyond load carrying capabilities, innovative designs and the utilization of novel multifunctional structural composite materials with embedded advanced sensors applied to battery enclosure assemblies that can sense, diagnose, and respond to thermal runaway and mitigate fire propagation in real-time. This development would provide product users with early warnings prior to its catastrophic failure and help maximize the overall battery performance. Another area of interest is in designs that can provide a safe containment of heat from failed battery cells and prevent the remaining battery cells/modules from getting into thermal runaway. An effective containment of flames and debris during any thermal runaway event is critical to protecting both personnel and vehicles.

This subtopic is to address thermal management issues with advanced materials and manufacturing technologies, for example: advanced coolants, thermal interface materials, innovative design approaches, and intelligent thermal management systems as well as to develop vehicle or structural materials strategies, at the EV battery, module, and/or cell level, that reduce the likelihood of the cascading EV fires. Demonstration of proof-of-concept for improvements on thermal runaway propagation and containment in a small level prototype that can simulate the actual thermal runaway is also an interest.

Potential applications could include, but are not limited to:

1. Novel battery components' composition/construction to reduce the likelihood of thermal propagation;
   - (a) Proposed solutions to mitigate thermal runaway should use lightweight, low-cost materials.
   - (b) Proposed solutions should consider one of the cell types currently used in the automotive industry, considering the thermal energy of the cell in the design process

2. Proposed solutions must be different than conventional and beyond the current state-of-the-art technologies;
3. Theoretical predictions with experimental verification;
4. Develop a cost model of fire-retardant materials using life cycle analysis (LCA).

Expectations at the end of Phase 1

- A material design solution validated for preventing thermal runaway propagation, either through virtual simulations or in small prototype equipment. The cell-to-pack mass ratio is targeted to be better than 65%.
- A mass and cost estimate of proposed solutions per kWh of cell energy

Expectations at the end of Phase II:

- Material solution validated for mechanical loads, such as cell expansion and contraction
- Optimization of the material solution for mass and cost, while maintaining the required thermal and mechanical performance
- Demonstration of the material solution in a representative battery enclosure containing three or more cells in a pack

Applications Discouraged:

- Cell electrochemistry development
- Non-Li-ion batteries
- Batteries of a size or design not relevant for EVs
- Auxiliary batteries for EV application

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

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1. Liu, Xu, Weng, et al., (2020), Phase **13**, 4622, Phase Change Materials Application in Battery Thermal Management System: A Review, https://doi.org/10.3390/ma13204622
2. Rui, Feng, Wang, et al., 2021, Synergistic effect of insulation and liquid cooling on mitigating the thermal runaway propagation in lithium-ion battery module, https://doi.org/10.1016/j.applthermaleng.2021.117521, (October 29, 2023)
3. Wong, Li, Rui, et al., 2024, Mitigating thermal runaway propagation in high specific energy
4. lithium-ion battery modules through nanofiber aerogel composite material, Energy, 307, 2024, Energy | Vol 307, 30 October 2024 | ScienceDirect.com by Elsevier (October 29, 2024) Wang, Zhao, Zhan, et al, 2024, Flame retardant composite phase change materials with MXene for lithium-ion battery thermal management systems, Journal of Energy Storage, **86**, Part A, (2024), 111293, ScienceDirect.com | Science, health and medical journals, full text articles and books. (October 29, 2024)
5. 5. Clean Technologies and Environmental Policy, (2020) **22**: 1213-1214, Volume 22, Issue 6 | Clean Technologies and Environmental Policy (October 29, 2024)

6. 6. Pham, Faheem, Chun, et al., 2021, Adv. Energy Mater., (2021), **11**, 20037, Advanced Energy Materials: Vol 11, No 11 (October 29, 2024)

f. EV Battery Firefighting Technologies

Several potential causes can lead to thermal runaway in EV batteries, leading to thermal propagation to other cells/modules and causing EV battery fires. Examples of these causes are manufacturing defects, overheating, internal shorting events, overheating, corrosion from saltwater intrusion, and crashes. While fire risk for EVs appears to be lower than for conventional vehicles, because EVs make up an increasing fraction of on-road passenger vehicles, VTO is interested in technology opportunities to improve the ability of emergency responders to avoid and fight battery fires.

Lithium-ion batteries in EV fires burn more intensely than conventional vehicle fires, and first responders face potential exposure to electric shock, toxic fumes, thermal runaway, battery ignition and reignition, and stranded energy when systems and components are no longer working as intended [1,2]. Emergency responders may let lithium-ion fires burn until they self-extinguish, which can take hours or days, or employ potentially massive amounts of water (even up to 20,000 gal) to cool batteries, extinguish fire and smoke, and prevent reignition, which may tax available water resources [1,2].

This topic seeks innovative solutions to more rapidly extinguish Li-ion battery fires in EVs. These solutions should:

- Reduce water usage;
- Extinguish fires substantially faster than conventional firefighting techniques based on water; and
- Reduce risk to first responders, including by reducing their proximity to the vehicle and/or exposure to toxic vapors resulting from a battery fire.

Examples of solutions include (but are not limited to):

- Alternative materials that perform better than water to extinguish battery fires; environmentally-benign firefighting media are preferred.
- Improved design or techniques for improved water/firefighting media to battery pack. An OEM letter of support for solutions based on modified pack/EV design is preferred, and proposal must evidence the feasibility to incorporate the innovation.

Phase I should clearly identify the innovation and compare its ability to fully extinguish (no reignition) EV battery fires to water in substantially less time. At the

end of Phase II, the project should demonstrate the firefighting innovation in practice (can be at smaller scale than full EV pack).
Proposed solutions for battery cell design or chemistry, non-Li-based batteries, battery cells/packs of a size not relevant to EVs, or for thermal runaway mitigation materials are not of interest for this topic.

Questions – contact Haiyan Croft, Haiyan.croft@ee.doe.gov

References:

1. 1. National Transportation Safety Board, 2020, "Safety Risks to Emergency Responders from Lithium-Ion Battery Fires in Electric Vehicles." https://www.ntsb.gov/safety/safety-studies/Documents/SR2001.pdf (October 29, 2024)
2. 2. U.S. Fire Administration, 2023, "U.S. Fire Administrator's Summit on Fire Prevention and Control." https://www.usfa.fema.gov/downloads/pdf/summit/2023-factsheets/ev-and-energy-transition.pdf (October 29, 2024)

g. Electrified Hydraulic Components for Off-road Equipment

As demand for electrified equipment increases, the need for electrified hydraulic components becomes more important to enable optimized equipment operation. Further, with greater hybridization necessary to reduce fuel consumption, hydraulic component efficiency improvements are important. Current designs impose significant throttling losses while being extremely robust. Typical components in the complete hydraulic system are pump, lines, valves, and work cylinders.

Phase I work will concentrate on system design and simulation of the technology chosen to replace and/or augment existing shaft-driven, throttled hydraulic pumps and valves. The goal is at least a 50% reduction in energy usage through electrification while maintaining similar durability to conventional systems.
Phase II work will focus on testing, industrialization, and commercialization of the components. During Phase II, a system level test will be conducted on representative equipment work cycles to demonstrate the efficiency improvement. Finally, the system must undergo a reasonable durability test to assess practical lifetime.

All submissions must meet following criteria:

- Proposals must focus on off-road equipment applications, but it is recognized that such technologies are likely to be sufficiently generic to be adopted to other applications.
- Proposals should focus on complete system replacement with concepts including electrified valves/pumps, directly driven cylinders/actuators, on-demand pressure controls, and hydraulic hybrid architectures.
- Solutions should be cost competitive with existing hydraulic systems/components
- Solutions must meet industry standards for equipment lifetimes and operating environments.

- For proposals which include the use of a working fluid, fluid specifications should be comparable to existing hydraulic fluids.
- System working voltages are expected to be in the range of 48 to 800 V, but applications are not limited to that range; however, appropriate safety considerations are required for higher working voltages.

  Questions – Contact: Nick Hansford, nicholas.hansford@ee.doe.gov

h. 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. The EEMS sub-program within VTO 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. EEMS 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.

The VTO Annual Merit Review database and through Annual Progress Reports provide an overview of the EEMS sub-program. 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.
All LOIs/applications must:

- **Target one of the following specific areas of interest**.
  - Technologies to enable, optimize, and/or encourage first-mile/last-mile connectivity of mass transit services to micromobility or other modes of transportation.
  - Technologies that enable or help optimize intermodal freight. Technology that improves the efficiency of intermodal facilities and surrounding right-of-way (e.g. rail and roads). Proposals must show net energy reductions, while considering inducements to more energy intensive modes.
  - Technologies that improve the energy efficiency of first-mile to last-mile freight operations and end customer delivery.
- **Clearly communicate the following.**
  - Specify the work to be done as part of Phase 1, in both the LOI and **the full proposal's workplan.** For the full proposal's workplan please identify:

        - What proposed Phase 1 work is dependent on funding or work outside of the SBIR grant
        - How they will fulfill the SBIR grant requirements **should any other grants or dependent work fail** to be resolved in a timely manner
    - Explain how the proposed project innovates upon the state of the art and will lead to energy savings
        - State of the art includes completed and in-progress work by VTO, other DOE offices and federal agencies, state and local governments, and by academia and/or the private sector
    - Address the inefficiency/problem they are addressing;
    - Show how their solution will improve efficiency and/or convenience[29] and how this improvement will be measured (described in terms of reductions in carbon production, energy use, fuel consumption, or other appropriate metrics)
    - Make it clear what new knowledge is being developed as part of each of the proposed phases and what will be published and shared vs. kept proprietary.

Descriptions just of products and/or business plans, which do not include specific research and development work are discouraged. Applications that are primarily focused on procurement are discouraged. EEMS recognizes that smartphone applications ("apps") may be a part of a transportation solution. However**, applications whose primary effort appears to be in app development will be discouraged**. Proposals only addressing a single vehicle, a single vehicle component, or physical right of way design, are discouraged. **Approaches must be systemic and include some combination of operations, design, planning, etc.**

Awarded applicants will be invited to the DOE VTO Annual Merit Review (AMR) in May or June. Applicants are not required to attend but may choose to allocate a portion of their budget to cover this expense if they choose to attend. Awarded applicants who choose to publish or share data publicly are encouraged, but not required, to use the Livewire data platform. Awarded EEMS projects may be invited to use the Livewire data platform, free of charge. Applicants may budget for staff time to use the Livewire data platform and EEMS may provide training on its use. **The preparation of the SBIR Phase 2 grant application, or for any grant or fundraising opportunity, may not be included in the budget of work funded work by this grant**.

Questions relating to the EEMS subtopic– Contact: Dr. Avi Mersky, Vehicle Technologies Office, Avi.Mersky@ee.doe.gov, and CC Energy Efficient Mobility Systems (EEMS), eems@ee.doe.gov. **All contact to EEMS for SBIR applications**

[29] Please see The U.S. National Blueprint for Transportation Decarbonization (energy.gov), for appropriate definitions

should be in writing only. Questions relating to the SBIR application or administrative process should be sent to sbir-sttr@science.doe.gov.

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 2024,
wind power provided more than 10% of U.S. electricity and accounted for 12% of new electricity capacity, representing $10.8 billion in capital investment and supporting more than 125,000 American jobs[3].

As one of the most cost-effective sources of electricity in America, wind energy is well-positioned for future growth. 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.
- Include projections for price and/or performance improvements that are tied to a baseline (i.e., 100% Clean Electricity by 2035 Study [4], wind technology market reports[5] 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.

C60-14. MAINTENANCE FOR NEXT GENERATION WIND PLANTS

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

Operational expenditures (OpEx) represent one of the largest contributions to the levelized cost of utility scale wind energy both on land and offshore [6]. Offshore, OpEx can be more than twice as costly per kilowatt of capacity than for land-based wind, and this is due in large part to the higher difficulty in accessing turbines and performing operations and maintenance (O&M) procedures [7]. In May 2024, WETO released “An Operations and maintenance Roadmap for U.S. Offshore Wind” [8] that details the expected challenges of maintaining the growing offshore wind fleet along with the opportunities for research and development (R&D) to mitigate some of these challenges and ensure a cost-effective and sustainable industry. Improved maintenance capabilities can contribute to reducing accessibility barriers, safety risks, and downtime, thereby reducing the overall OpEx costs for a wind farm. This topic seeks to support the development of advanced and potentially autonomous O&M technologies that can assess and perform maintenance tasks quickly and effectively while improving the productivity and reducing exposure of maintenance workers.

a. Cranes and alternative technologies for major component exchange

Increases in turbine nameplate capacity, the height of the towers, number of turbines, and (for offshore) the growing distance from port all present challenges for in-service maintenance. For a sense of scale, there are roughly 75,000 wind turbines across the U.S. [9], average land-based wind turbine hub heights are now above 100m and trending higher [10], and an offshore 15MW hub and nacelle can weigh more than 800 metric tons [11].

Technology proposed under this subtopic should pursue one or more of the following objectives:

- Advance crane design, configuration, and deployment strategies (e.g. climbing cranes) to enable heavier and higher lifts without the cost and schedule impacts of large heavy-lift vessels and cranes [12].
- Develop new technologies or alternative approaches for crane-less operations, including both installation and maintenance.
- Improve the safety of in-field and at-sea component maintenance, emphasizing reduced exposure on site and at height.
- Lower the mobilization cost, increase the speed of deployment, and provide expanded weather windows for maintenance activities.
- Enhance the cost-effectiveness of *in situ* maintenance for various floating offshore wind scenarios.

b. Autonomous maintenance and decision support

DOE supports advanced R&D to improve system health while minimizing labor on site, at height, and in the open sea, including incorporation of new sensors, sensor fusion, and artificial intelligence into defect and anomaly detection, diagnosis, prognostics, and maintenance planning.

Technology proposed under this subtopic should pursue one or more of the following objectives:

- Develop the ability to measure, store and transmit quantities of interest from where access and maintenance is challenging and/or costly, or where current commercial offerings fail to provide data of sufficient resolution or accuracy.

- Improve the lifespan, performance, or practical usefulness of sensors that already exist such that they can be used beyond short, heavily monitored field campaigns and can provide operators with useful data throughout the turbine design life.
- Fuse sensor data from multiple new or existing sources within the wind farm to predict downtime substantially in advance of failures, inform anomaly or failure detection, evaluate potential maintenance strategies, and determine a recommended course of action.
- Leverage data and digital technologies to improve existing maintenance processes, create new sources of wind project revenue or value, or improve coordination and communication of maintenance activities across the wind industry [13]
- Employ robotics or other automation technologies for wind plant inspections and maintenance [14] with appropriate levels of autonomy ranging from technician productivity assistance to full autonomy.

Please refer to the American Wind Energy Association's 2017 O&M Recommended Practices [15] or similar resources when identifying maintenance activities to automate.

Applications specifically not of interest in either subtopic

- External optical inspection technologies
- Digital twin development without a clearly identified use-case and connected physical asset(s)
- AI-focused proposals without a clearly identified use-case and training datasets
- Proposals lacking sufficient rationale and detailed estimates of the cost, schedule and performance impacts of the technology.

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

References

1. U.S. Department of Energy (DOE), Wind Energy Technologies Office (WETO), 2024, https://www.energy.gov/eere/wind/wind-energy-technologies-office (October 29, 2024)
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C60-15. WATER POWER TECHNOLOGIES: BASE APPROPRIATIONS TOPICS

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

Hydropower

a. Municipal and Industrial Conduit Hydropower
b. Innovations in data collection, analytics, models and tools
c. Pumped Storage Hydropower Innovative Concepts

Marine Energy

d. Co-Development of Marine Energy Technologies
e. Development of Standardized Modular Power Electronics for Grid-Compatible Marine Energy Systems
f. Advances in Overtopping Wave Energy Converters for Coastal Structures
g. Next-Generation Tidal and River Current Energy Technologies for Arctic/Alaskan Communities
h. Feasibility of Co-locating Marine Energy and Offshore Wind

The U.S. Department of Energy's (DOE) Water Power Technologies Office (WPTO)[1] 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 SBIR and STTR applications related to both Hydropower and Marine Energy technologies in the eight 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
- Justify all performance claims with theoretical predictions and/or relevant experimental data
- Include a post-Phase II plan that outlines future work plans, including how companies will grow and ensure their systems reach end users

WPTO will provide feedback to all Letters of Intent received for this topic.

Contact: water.sbir@ee.doe.gov

References

1. DOE, 2024, Water Power Technologies Office, https://www.energy.gov/eere/water/water-power-technologies-office (October 29, 2024)

a. Municipal and Industrial Conduit Hydropower

Background

The topic seeks innovative technologies and approaches to expedite the deployment of conduit hydropower in municipal and industrial systems. These applications leverage excess pressure within existing or new piped water systems to produce local, renewable electricity that can improve the energy resilience of water distribution, wastewater treatment, and thermoelectric cooling systems, among others. For example, one common application is placing conduit hydropower turbines in parallel to pressure reducing valves (PRVs) to capture the pressure that is typically dissipated by these devices. Conduit hydropower may be used for behind-the-meter power to support continued operation during grid outages or used in front of the meter for generation revenues.

In 2022, Oak Ridge National Laboratory released *An Assessment of Hydropower Potential at National Conduits* [1]. This study identified approximately 378MW of industrial conduit hydropower potential and 374MW of municipal potential across the United States. These are conservative, reconnaissance level estimates owing to the lack of publicly available data for these systems. The study identified the need for improved resource characterization methods, streamlined development processes, efficient generation technologies and concepts, and increased public awareness on this opportunity. As such, this topic is open to not only small businesses that develop cost-effective generation technologies, but also small businesses with innovations or services that support siting, feasibility assessment, development, and other activities that meet these needs.

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. Any 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 activities that will lead to increased deployment of conduit hydropower in municipal and industrial systems. 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)
- A description of the pervasiveness of applicability across U.S. water systems, using available resource assessments 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 must 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 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., water utilities, municipalities, or industrial companies) where the Phase II deployment will occur

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

References

1. Kao, S.-C., Hansen, C., & DeNeale, S.,2022,, ORNL, An Assessment of Hydropower Potential at National Conduits. https://info.ornl.gov/sites/publications/Files/Pub176069.pdf (October 29, 2024)

b. Innovations in Data Collection, Analytics, Models and Tools (Energy-Water Nexus Crosscut)

Background

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

1. *data collection* using advanced sensing and monitoring technologies (e.g., in powerhouses or hydropower reservoirs), data collection methods, and new instrument design that capture new variables
2. *analytics* that use and apply new methods (e.g., artificial intelligence) to draw upon new insights
3. *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)
4. *tools* that translate data and models for decision-making, resource management and other applications (e.g., flood risk assessment)

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

- Solve challenges in sensors, instruments, or monitoring systems designed to collect data that supports the development, longevity, efficiency, or resilience of hydroelectric generation. This includes new approaches to data collection like AUVs, sensor platforms, or remote sensing.
- Solve gaps and challenges in the synthesis of existing 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 applications has remained challenging.

- Develop advanced models that meet the evolving needs of hydropower owners and operators, or other relevant stakeholders seeking insights into hydropower operations and management, and/or,
- 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 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 directly apply to hydropower. Proposals should clearly address challenges and opportunities in one or more of the following: data collection, analytics, modeling, or tools.

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

- eDNA
- Modeling
- Inflow forecasting
- Fish passage
- Asset management
- Water quality, quantity, or demand modeling
- Artificial intelligence and machine learning

Application Requirements

Applications must involve research, development, and/or demonstration of their innovative sensors, 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.

Competitive applicants must demonstrate knowledge, experience, and capabilities in engineering sensors, adapting existing ones for innovative purposes, analyzing data, or developing models and tools.

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 systems or industries
- A description of the pervasiveness of applicability
- Example(s) of potential end-users and their data collection, analysis, and/or decision-making needs

- A detailed plan for the development or enhancements of the technology, analytics, model, or tool 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
- If collecting data or developing a sensor:
    - 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 data collection system
- 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 must state how awardees will:

- Identify and develop detailed plans for possible testing and demonstration, including:
    - target end-users
    - specific partners and capacity of partnerships
    - budget
- If developing a sensor or device:
    - Build and test the sensor solution as outlined in Phase I
    - Finalize the design of the sensor along with any necessary system support
    - Perform a series of tests on the sensor solution over a range of operational conditions
- 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.
- Complete the research on the commercial potential of the solution
- Develop a report on hydropower 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

Background

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

Application Requirements

Competitive applicants must demonstrate knowledge, experience, and capabilities in developing hydropower and PSH technologies. Applications must 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
2. How the system would operate, using conceptual designs, drawings, or schematics of the proposed system with estimated physical dimensions

The applicants must 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
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
   c. potential end-use partners and how the technology will benefit them

During Phase II, awardees will:

1. Conduct laboratory and/or field tests designed during Phase I
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
   d. policy and community considerations regarding target site and partners

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

References

1. Somani, A., et al, 2021, Hydropower Value Study, *PNNL-29226,* https://www.energy.gov/sites/prod/files/2021/01/f82/hydropower-value-study-v2.pdf (October 29, 2024)
2. National Renewable Energy Laboratory, 2021, Storage Futures Study, *NREL,* https://www.nrel.gov/analysis/storage-futures.html (October 29, 2024)
3. DOE: HydroWires, 2020, Pumped Storage Hydropower FAST Commissioning Technical Analysis (energy.gov) (October 29, 2024)
4. DOE, 2024, Water Power Technologies Office, https://energy.gov/hydrowires (October 29, 2024)
5. DOE, 2024, Water Power Technologies Office, https://www.energy.gov/eere/water/pumped-storage-hydropower (October 29, 2024)
6. DOE:HydroWires, 2022, A Review of Technology Innovations for Pumped Storage Hydropower (anl.gov) (October 29, 2024)
7. Pumped Storage Hydropower International Forum, 2021, Innovative Pumped Storage Hydropower Configurations and Uses (October 29, 2024)
8. ORNL, 2015, Evaluation of the Feasibility and Viability of Modular Pumped Storage Hydro (m-PSH) in the United States (October 29, 2024)
9. PNNL,2024, Energy Storage Cost Performance Database, https://www.pnnl.gov/ESGC-cost-performance (October 29, 2024)

d. Co-Development of Marine Energy Technologies

Background

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 Initiative. Specifically, this subtopic seeks to support the development of industry projects that link marine energy technologies together with blue economy energy end users to co-develop solutions specific to energy constraints.

A common underlying input for many of the activities in the blue economy is energy: fuel for ships, batteries for underwater vehicles, or high-pressure seawater for desalination systems. While some activities have access to cheap and reliable sources of energy, others do not. Energy inaccessibility limits operations and adds unnecessary costs. Removing or reducing these energy constraints through energy innovation could open new pathways for sustainable economic development. 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 a deliverable during the period of performance.

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 must 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
- 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

References

1. DOE, 2019, Water Power Technologies Office, *Powering the Blue Economy Report,* https://www.energy.gov/eere/water/articles/powering-blue-economy-report (October 29, 2024)
2. NREL, 2019, *Enabling Power at Sea: Opportunities for Expanded Ocean Observations through Marine Renewable Energy Integration*, https://www.nrel.gov/docs/fy20osti/74459.pdf (October 29, 2024)
3. Water Power Technologies Office, 2023, https://eere-exchange.energy.gov/FileContent.aspx?FileID=89a224a1-6062-4567-a52d-66ddca0aa158 (October 29, 2024)
4. DOE, 2024, *Combating the Climate Crisis*, https://www.energy.gov/combating-climate-crisis (October 29, 2024)
5. DOE, 2024, *Promoting Energy Justice*, https://www.energy.gov/promoting-energy-justice (October 29, 2024)

e. Development of Standardized Modular Power Electronics for Grid-Compatible Marine Energy Systems

Background

The integration of marine energy into existing power grids faces significant challenges due to the lack of standardized power electronics that can meet grid connection requirements, particularly for variable renewable energy sources. The aim for this topic area is to develop a modular and standardized power electronics architecture, with design specifications that can be adapted to various marine energy converters, such as wave and tidal energy devices. The study will focus on ensuring grid code compliance, enhancing fault ride-through capabilities, and optimizing power quality as addressed in the IEC TS 62600 –30. In addition, this study should evaluate different control strategies, and semiconductor materials that support standardized cost-effective power electronics system for marine energy. The outcome will provide a framework for establishing standards that facilitate easier and more cost-effective grid integration of wave or tidal/current energy technologies.

Application Requirements for Phase I

- Proposals should describe either wave energy device or tidal energy device power electronic specifications and integration within the PTO system.

- Proposals should describe representative grid connection requirements, IEEE standards and compliance for the respective marine energy converter technology.
- Proposals should describe a standardized power electronics interface for different marine energy converters to meet the diverse requirements of grid connections.
- Proposals should investigate and describe specifications for a modular design approach that creates a flexible, scalable power electronics solution adaptable to different power levels.
- Proposals should clarify the control algorithms for power electronics to handle the variability and intermittency of respective marine energy, managing grid faults, voltage dips and harmonic issues while ensuring compliance with grid codes.
- Proposals should evaluate the use of wide-bandgap semiconductor materials for improved efficiency and reliability in power conversion demonstrating more efficient, reliable, and easier to integrate marine energy into the grid.
- Proposals should provide a framework for standards and certification processes to simplify and accelerate marine energy grid integration.

Application requirements for Phase II

- Proposals should design, model and build based on Phase I specifications a cost-efficient power electronics system to be bench tested according to IEC TS62600-30.

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

f. Advances in Overtopping Wave Energy Converters for Coastal Structures.

Background

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 complex environmental and operational risks of offshore marine energy deployment. Although the development of these technologies remains nascent in the U.S., there are several successful long-term, international deployments. These coastal structure integrated (CSI) WECs generally fall under three archetypes, oscillating water column (OWC), wall-mounted heave, and overtopping devices (OT).

This topic focuses on overtopping devices that typically harness energy through the run-up of a wave onto a coastal structure to fill a reservoir that empties through a low-head turbine (or a set of turbines). These differ from most other WEC designs since they do not directly use the kinetic energy of a wave but instead harvest energy after it has been turned into potential energy in the form of pressure head.

The possible value propositions of marine energy devices integrated with coastal protection structures are to provide coastal defense and energy extraction, fewer 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.

The goals of this Overtopping CSI-WEC topic include:

- Create innovative OT-CSI-WEC designs for integration into both new and existing coastal infrastructure that maximize energy production and resiliency
- Assist startups and entrepreneurs who have novel CSI-WEC concepts in further developing these into viable solutions
- Utilize innovative construction and or integration techniques for installing these systems onto new or existing infrastructure. This can include modular prebuilt systems, 3D printing technologies, etc.

Application Requirements

In addition to the requirements for all Water Power Technologies subtopics described at the beginning of this topic, for these Phase I, competitive applicants must demonstrate knowledge, experience, and/or capabilities in developing marine technologies.

Applicants must include as many of the following points in their proposals where appropriate:

- 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
- A description of the expected power output (kilowatts)
- A description of the expected dimensions of the design relative to the size of the infrastructure
- Initial description of potential follow-on Phase II work

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

References

1. Office of Economic Impact and Diversity, 2024, *Justice40 Initiative, Energy Justice Policy*, https://www.energy.gov/diversity/justice40-initiative (October 29, 2024)

g. Next-Generation Tidal and River Current Energy Technologies for Arctic/Alaskan Communities

Background

This topic focuses on the development of reliable, resilient, and cost-effective tidal-stream and river current technologies tailored to the unique challenges of remote, high-latitude, arctic environments. The goal is to encourage new designs that address the harsh environmental challenges of the Arctic while creating robust, modular, and scalable solutions for remote community energy systems. The core program objective is to build a robust pipeline of technologies that generate power from a diverse and wider array of tidal and riverine resources, ensure robust power performance, resiliency, and reliability in harsh environments, and reduce the overall cost of energy.

Key Focus Areas

- **Regional Adaptation and Challenges**:
    - Address the environmental and operational conditions specific to regions like Alaska and the Arctic, including ice (e.g., Yukon River), frazil ice, turbulence, sedimentation, riverbed scour, debris, and seasonality of river flows.
    - Develop strategies to handle low-velocity cut-in speeds, ensuring reliable power generation in varied and low-resource environments.
- **Modular and Scalable Technology Development**:
    - Prioritize modular designs that can be easily adapted and scaled for gradual power capacity expansion.
    - Focus on solutions that are easy to install, durable in harsh environments, and require minimal maintenance, with special consideration for ice-resistant materials.
    - Develop and model systems ready for microgrid integration with necessary power electronics to control frequency and voltage on remote Alaskan microgrids
- **Tidal-Stream Technology Innovations**:
    - Develop tidal-stream energy devices that harness power from shallow stream resources and confined channels, enabling energy generation from locations previously considered too low-resource or inaccessible.
    - Incorporate control strategies that enhance operational simplicity without compromising robustness, enabling low-complexity solutions for distributed generation.
    - Designing-For-OpEx (DFO) approaches emphasizing operations and maintenance aspects of the system design. This approach should be about reducing the high costs of operations/maintenance as well as designing systems that can be locally maintained without advanced technical expertise.

- **Distributed Generation for Local Loads**:
    - Focus on technologies that can be sited close to communities as part of a distributed energy generation scheme, reducing transmission losses and increasing reliability in isolated or off-grid systems.
- **Environmental and Resource Diversity**:
    - Encourage the exploration of diverse locations for energy capture, including shallow tidal streams and arctic river environments, expanding the applicability of tidal and riverine energy beyond traditional high-energy sites.
- **Novel Approaches:**
    - While the primary focus of this topic is on proven tidal-stream and river current technologies, it also seeks to explore emerging, high-potential designs such as those advanced by ARPA-E's SHARKS program [1]. These devices offer unique advantages, particularly in low-velocity or turbulent environments, making them promising candidates for distributed generation in challenging locations like shallow arctic rivers or tidal streams.

Application Requirements

- A conceptual and or full design of the proposed system
- Explain the value proposition of their design to coastal, island, and riverine communities, specifically value to energy resiliency, distributed generation strategies, hybrid power generation strategies, and potentially microgrid or heating system integration
- A description of survival strategies
- A description/storyboard of deployment, transport, and other logistical challenges that are key to remote Alaskan areas
- Description of maintenance /OpEx strategies relevant to design - design for maintenance and local manufacturing preferred
- 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
- 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
- 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. The key hypothesis, as set by the topic area, is to

experimentally prove designs that can survive and are well-suited for harsh engineering environmental challenges of Alaska

- 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
- Projects should include physical testing in Phase II of critical systems and sub-systems in the water to validate design assumptions of proposed design

Applicants are encouraged to use TEAMER (Testing & Expertise for Marine Energy) [2] for experimental validation and technical assistance requests as appropriate.

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

References

1. ARPA, 2020, *Submarine Hydrokinetic And Riverine Kilo-Megawatt Systems (SHARKS*) - SHARKS | arpa-e.energy.gov (October 29, 2024)
2. TEAMER, 2024, *Testing & Expertise for Marine Energy* - https://teamer-us.org/(October 29, 2024)

h. Feasibility of Co-locating Wave Energy and Offshore Wind

Background

Combining multiple renewable energy technologies, such as including wave energy on an offshore wind farm, may reduce costs of electricity generation due to shared ocean space and the ability to leverage existing infrastructure for deployments (e.g., cables). Additional benefits associated with the co-location of wave energy and offshore wind include reductions in power variability and increased power density and energy yield. Co-location also decreases the spatial footprint of offshore energy projects that may otherwise be sited separately, which can help alleviate spatial conflicts and challenges with other ocean users and industries.

This topic seeks applications that can demonstrate the feasibility of co-locating offshore wind and wave energy. During Phase I, awardees are expected to conduct a paper study in preparation for a numerical study in Phase II. Phase I activities include feasibility analyses, economic analyses, industry engagement, an assessment of integration challenges, and considerations that need to be made related to permitting and siting. Phase II activities include resource assessments, identification of optimal sites and/or conditions for co-location, and numerical design studies for optimal layout and energy generation.

Application Requirements
In addition to the requirements for all Water Power Technologies subtopics described at the beginning of this topic, for these Phase I proposals, competitive applicants must demonstrate knowledge, experience, and/or capabilities in advancing marine technologies. Applications must have a coherent plan for the project over the duration of the award where a clear path can be understood.

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

- A description of activities to advance research and development on the feasibility, opportunities, and challenges of siting wave energy on offshore wind farms
- A clear description of the innovation that articulates the value proposition of co-locating offshore wind and wave energy
- The development of a comprehensive analysis that demonstrates how wave energy reduces power variability of offshore wind and how co-location increases the power density and energy yield for an offshore energy project
- Characterization of the reduction in spatial footprint and required acreage if co-locating offshore wind and wave energy
- Economic analyses to assess the costs of co-locating offshore wind and wave energy and identification of cost reductions
- An assessment of environmental impacts of co-locating offshore wind and wave energy
- A description of the impact to permitting timelines associated with leveraging existing offshore infrastructure
- Identification of constraints on where and how offshore wind and wave energy can be deployed, including potential locations and sites as examples
- A plan for industry engagement
- A description of integration challenges
- Use case(s) with applicability to wave energy systems and offshore wind that consider existing locations slated for offshore wind development
- A description of the pervasiveness of applicability
- Initial description of Phase II work, including plans for resource assessments, identification of optimal sites and/or conditions for co-location, and numerical design studies for optimal layout and energy generation

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

References

1. Gonzalez, H. D. P., Bianchi, F. D., Dominguez-Garcia, J. L., & Gomis-Bellmunt, O., 2023, Co-located wind-wave farms: Optimal control and grid integration. *Energy*, *272*, 127176. Co-located wind-wave farms: Optimal control and grid integration - ScienceDirect (October 29, 2024)
2. Wan, L., Gao, Z., Moan, T., & Lugni, C., 2016, Comparative experimental study of the survivability of a combined wind and wave energy converter in two testing facilities. *Ocean Engineering*, *111*, 82-94. Comparative experimental study of the survivability of a combined wind and wave energy converter in two testing facilities - ScienceDirect (October 29, 2024)
3. Macsumic, Z., 2024, Ørsted Partners with Compatriot Company to Investigate Potential of Wave-Wind Combo, https://www.offshorewind.biz/2024/07/04/orsted-partners-with-compatriot-company-to-investigate-potential-of-wave-wind-combo (October 29, 2024)
4. Jonasson, E., Temiz, I., 2023, Grid Value of Co-Located Offshore Renewable Energy, Vol. 15 (2023): Proceedings of the European Wave and Tidal Energy Conference, https://doi.org/10.36688/ewtec-2023-313 (October 29, 2024)

C60-16. WATER POWER TECHNOLOGIES: BIPARTISAN INFRASTRUCTURE LAW TOPIC (STTR 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: YES
Accepting SBIR Fast-Track Applications: NO	Accepting STTR Fast-Track Applications: NO

The U.S. Department of Energy's (DOE) Water Power Technologies Office (WPTO)[1] 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 accepting Phase I STTR applications related to both Hydropower and Marine Energy technologies:

a. Marine Energy Technologies

Marine energy technologies, including tidal, current, and wave energy systems as well as ocean thermal energy conversion, suitable for microgrids and for remote, islanded, and isolated communities

b. Hydropower Technologies

Hydropower technologies, including small hydropower and low-impact hydropower growth, and new technology development for both existing water infrastructure and new stream-reach applications that incorporate ecological and social objectives

WPTO will provide feedback to all Letters of Intent received for this topic.

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

References

1. DOE, 2024, Water Power Technologies Office, https://www.energy.gov/eere/water/water-power-technologies-office (October 29, 2024)

PROGRAM AREA OVERVIEW: OFFICE OF ENVIRONMENTAL MANAGEMENT

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

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

DOE also manages some of the largest groundwater and soil contamination problems and subsequent cleanup in the world. This includes the remediation of 40 million cubic meters of contaminated soil and debris contaminated with radionuclides, metals, and organics [1].

Remediation of contaminated soil and groundwater has been ongoing at United States Department of Energy (DOE) Office of Environmental Management (EM) sites for over four decades, yet site closure remains elusive at many of DOE’s complex groundwater sites, especially those complicated by challenging geologic, hydrologic, and chemical factors. DOE-EM is working to develop a consistent, complex-wide groundwater strategy. This strategy is being developed with two ultimate goals: (1) to provide actionable recommendations to shrink the remaining cleanup footprint over the coming decade, and (2) to identify overarching metrics that can be used to expedite and track cleanup progress.

For additional information regarding the Office of Environmental Management priorities, please visit us on the web at https://www.energy.gov/em/annual-priorities-strategic-vision-and-program-plan.

C60-17. *IN-SITU* CHARACTERIZATION METHODS

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

Reducing human effort and involvement in collection of analytical data has potential to greatly reduce the cost associated with treatment of S&GW plumes, and long term monitoring at DOE sites.

a. **Development of new technologies to advance autonomous monitoring of soil and groundwater contamination at sites undergoing both active and passive remediation.**

   Sensors are needed for a variety of systems with challenges that include remote siting, long-distances between sensor and monitoring stations, outdoor sites, and low concentrations for contaminants of interest.

   Measurements of interest:
   - Geophysical
   - Geochemical
   - Water-quality data
     - pH
     - Conductivity

   Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov; Charles Denton, Charles.Denton@em.doe.gov

b. **Deep aquifer characterization**

   Develop cost effective methods for accessing/characterizing contamination in deeper aquifers (with contamination in overlying aquifers likely).

   Measurements of interest:
   - Geophysical
   - Geochemical
   - Water-quality data
     - pH
     - Conductivity

   Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov; Charles Denton, Charles.Denton@em.doe.gov

c. **Other**

   Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov; Charles Denton, Charles.Denton@em.doe.gov

References

1. Singha K., F.D. Day-Lewis, T.C. Johnson, and L.D. Slater. 2015. "Advances in interpretation of subsurface processes with time-lapse electrical imaging." *Hydrological Processes* 29, no. 6:1549-1576. PNNL-SA-110809. doi:10.1002/hyp.10280,

https://people.mines.edu/ksingha/wp-content/uploads/sites/44/2018/12/singha_etal2014.pdf (October 29, 2024)
2. Johnson T.C., C.E. Strickland, J.N. Thomle, F.D. Day-Lewis, and R. Versteeg. 2022. "Autonomous Time-Lapse Electrical Imaging for Real-Time Management of Subsurface Systems." *The Leading Edge* 41, no. 8:520-528. PNNL-SA-172662. https://doi.org/10.1190/tle41080520.1 (October 29, 2024)
3. Thomle J.N., C.E. Strickland, T.C. Johnson, Y. Zhu, and J.C. Stegen. 2020. "A flux detection probe to quantify dynamic groundwater-surface water exchange in the hyporheic zone." *Groundwater* 58, no. 6:892–900. PNNL-SA-144934. doi:10.1111/gwat.13001, A flux detection probe to quantify dynamic groundwater-surface water exchange in the hyporheic zone. | Journal Article | PNNL (October 29, 2024)
4. Rockhold M.L., J.L. Robinson, K. Parajuli, X. Song, Z. Zhang, and T.C. Johnson. 2020. "Groundwater characterization and monitoring at a complex industrial waste site using electrical resistivity imaging." *Hydrogeology Journal* 28, no. 6:2115-2127. PNNL-SA-147892. doi:10.1007/s10040-020-02167-1, Groundwater characterization and monitoring at a complex industrial waste site using electrical resistivity imaging | Journal Article | PNNL (October 29, 2024)
5. Tso C., T.C. Johnson, X. Song, X. Chen, O. Kuras, P. Wilkinson, and S. Uhlemann, et al. 2020. "Integrated hydrogeophysical modelling and data assimilation for geoelectrical leak detection." *Journal of Contaminant Hydrology* 234. PNNL-SA-152552. doi:10.1016/j.jconhyd.2020.103679, Integrated hydrogeophysical modelling and data assimilation for geoelectrical leak detection | Journal Article | PNNL (October 29, 2024)
6. Strickland C.E., M.J. Truex, R.D. Mackley, and T.C. Johnson. 2018. Deep Vadose Zone Monitoring Strategy for the Hanford Central Plateau. PNNL-28031. Richland, WA: Pacific Northwest National Laboratory, https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-28031.pdf (October 29, 2024)
7. McAliley, W. A., Day-Lewis, F. D., Rey, D., Briggs, M. A., Shapiro, A. M., & Werkema, D. (2022). Application of recursive estimation to heat tracing for groundwater/surface-water exchange. *Water Resources Research*, *58*, e2021WR030443. https://doi.org/10.1029/2021WR030443 (October 29, 2024)
8. Johnson, T., C. Strickland, J. Thomle, F. Day-Lewis, and R. Versteeg. 2022. Autonomous time-lapse electrical imaging for real-time management of subsurface systems. *The Leading Edge* 41 no. 8: 520-528. https://doi.org/10.1190/tle41080520.1 (October 29, 2024)

C60-18. MITIGATION METHODS FOR DIFFICULT TO TREAT SOIL AND GROUNDWATER CONTAMINANTS

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 presence of species in soil and groundwater that are highly resistant to breakdown from the biological or chemical processes prevalent in S&GW is an area of increasing concern across industrialized nations. Mitigation is hampered by the difficulty in detection and lack of efficient treatment methods for these species.

a. Microplastics and PFAS

- Species of interest are:
  - AFFF
  - Perfluorooctanoic Acid
  - Perfluorooctanesulfonic Acid
- Methods for detection/quantification.
- Methods for effective treatment to include separation/immobilization or destruction of the contaminants.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov; Charles Denton, Charles.Denton@em.doe.gov

References

1. Environmental Protection Agency: Per- and Polyfluoroalkyl Substances (PFAS)
2. Interstate Technology and Regulatory Council: PFAS - Per- and Polyfluoroalkyl Substances
3. Agency for Toxic Substances and Disease Registry: Per- and Polyfluoroalkyl Substances (PFAS) and Your Health

C60-19. IMPROVEMENTS FOR DECONTAMINATION OF EQUIPMENT/STRUCTURES

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

Disposal of contaminated equipment and dismantling of contaminated structures is a significant portion of the EM mission as sites eliminate facilities no longer needed or past their service life. Improvements in performing these processes would increase worker safety, reduce the environmental risk from these processes and enable cost and schedule savings. Areas of interest include:

a. Characterization

Focuses on identifying the nature, magnitude, and location of the contamination (nuclides, chemical constituents) in the facility. General mapping of dose rates and airborne contamination (rad and nonrad) supports conduct of hazard analysis and risk assessment. Characterization data and documents accumulated during deactivation, if applicable, serves as a starting point. The characterization data provides considerations in defining, organizing, and planning the technical components of decommissioning projects.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov; Charles Denton, Charles.Denton@em.doe.gov

b. Decontamination methods

Decontamination processes reduce, remove, or neutralize radiological, chemical, or biological contamination and reduce the risk of exposure. Decontamination may be accomplished by cleaning or treating surfaces to reduce or remove the contamination; filtering contaminated air or water; subjecting contamination to evaporation and precipitation; or covering the contamination to shield or absorb the radiation. The use of natural decontamination process can also simply allow adequate time for natural radioactive decay to decrease the radioactivity

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov; Charles Denton, Charles.Denton@em.doe.gov

c. Fixatives

Fixatives can be used for Decommissioning and Maintenance of Radiological Facilities. Fixatives can deliver a process for reducing airborne radiological and/or chemical contamination and affixing loose contamination in place, thereby reducing contamination risk to employees and decreasing D&D cost and schedule. The developed process provides a reliable, unmanned method of introducing a coating that captures and fixes contamination in place within facilities.

Questions – contact: Latrincy Bates, Latrincy.Bates@em.doe.gov; Charles Denton, Charles.Denton@em.doe.gov

References

1. DOE, 1999, Office of Environmental Management, Decommissioning Implementation Guide (doe.gov) (October 29, 2024)

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]

C60-20. 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 four programs in FECM's Office of Carbon Management Technologies: Carbon Transport and Storage, CO_2 Conversion, Integrated Carbon Management, and Point Source Carbon Capture.

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

Applications are sought for the following subtopics:

a. Catalytic Conversion of Carbon Dioxide to Fuel (BIL Funded)

The FECM Carbon Conversion Program supports the research, development, and demonstration of technologies that convert captured carbon oxides, primarily carbon dioxide (CO_2), into economically valuable products such as chemicals, fuels, building materials, plastics, and bioproducts. The FECM Carbon Conversion Program focuses primarily on three conversion pathways encompassing biological uptake, catalytic conversion, and mineralization. Any of the three conversion pathways may incorporate reactive capture and conversion (RCC), which refers to an integrated process where a CO_2 rich sorbent/solvent is converted into product without requiring a purified CO_2 intermediate stream (reducing cost through process intensification and eliminating purification and transport of CO_2).

This topic area will support the catalytic conversion of CO_2 into fuel. Catalytic conversion pathways under the topic area should involve the reduction of CO_2 with hydrogen, hydrocarbons, and or electricity through multiple processes including but not limited to thermochemical, photochemical, or plasma-assisted (thermal and non-thermal) approaches. The topic area will <u>not</u> support R&D of electrochemical or microbially mediated conversion approaches, as to avoid redundancy with recent FECM funding opportunities or other DOE Offices, respectively[1,2].

The topic area is synergistic with other DOE efforts, including the Energy Earthshots Initiative, which aims to accelerate breakthroughs and adoption of more abundant, affordable, sustainable, and reliable clean energy solutions[3]. Specifically, the Clean Fuels & Products Shot supports projects that decarbonize the fuel and chemical industry through alternative sources of carbon to advance cost-effective technologies[4]. To meet the United States' goal of a net-zero carbon economy by 2050, the Clean Fuels and Products shot will evaluate alternative ways to make carbon-based products, and produce them in ways that minimize greenhouse gas (GHG) emissions to achieve U.S. net zero goals.

Grant applications are sought for the research and development of catalytic carbon conversion technologies to produce fuel that demonstrate life cycle analysis (LCA) greenhouse gas emissions that are at least 50% lower than equivalent incumbent products on a cradle to gate basis. The grant application must describe whether the fuel product is intended as a blending agent for fossil fuel or as a stand-alone drop-in replacement. The grant application must discuss what testing methodologies will be utilized to validate the performance of the fuel and, if applicable, blends thereof (e.g. ASTM D1655, D2069, D4814-22, and others as applicable). The Phase I work plan should include all testing necessary to determine whether the fuel meets the required performance specifications.

Grant applications must 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). Grant applications must identify the source of energy input into the system, including chemical (e.g. hydrogen), thermal, and or electrical. Grant applications should propose catalytic conversion pathways including but not limited to thermochemical, photochemical, or plasma-assisted (thermal and non-thermal) approaches. Grant applications should not propose electrochemical or microbially mediated conversion pathways, as these are not of interest.

The Phase I work plan should include preliminary life cycle analysis (LCA) and techno-economic analysis (TEA) to understand how the process emissions and economics of the fuel 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 catalytic conversion technologies to produce fuel which demonstrate life cycle greenhouse gas emissions that are at least 50% lower than an equivalent incumbent product on a cradle to gate basis
- Describing whether the fuel product is intended as a blending agent for fossil resources or as a stand-alone drop-in replacement, and discussing what testing methodologies will be utilized to validate the performance of the fuel
- Describing the CO_2 source and energy inputs that would be utilized in a commercial system
- 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. Digital Tools to Support Design and Materials Selection and Assurance of Operational Asset Integrity for CO2 Transport and Storage

This topic supports the development of new digital tools for CO2 transportation and/or storage systems that can assess hardware materials under various operating and fluid conditions and determine asset integrity constraints for the purpose of advancing safe and robust material selection, system design, and management of physical infrastructure.

To address the DoE's need for accelerating the commercial launch of a carbon capture, utilization and storage industry, new digital tools and technologies are desired to assess, evaluate, predict, and potentially monitor the asset integrity of carbon transportation systems and individual system components (e.g., booster equipment, pipelines, well casing, valves, tubing, cement, etc.) when exposed to carbon dioxide with various impurities and under a wide range of operating conditions (to include typical upsets) throughout an asset's design life. A proposed project can include research specific to benchmark and tune digital tool performance to testing results such as, but not limited to, fluid compatibility, chemical compatibility, material compatibility, corrosion, cracking, weld failure, and/or other potential material failure (burst, collapse, delamination, bubbling, etc.). Projects that successfully enter SBIR Phase II, would typically further develop and then test or demonstrate their tool in a real-world setting or application. At the end of SBIR Phase II, the result of a successful project will be a digital tool ready for commercial application either as a plug-in or stand-alone tool that supports proper metallic and non-metallic (e.g., elastomer) material selection within design and/or operational integrity management requirements for CO2 specific transportation or storage systems.

Questions – Contact: Paul Zandhuis, Paul.Zandhuis@NETL.DOE.GOV

c. Asset Integrity Assurance and Corrosion Mitigation for Surface and Subsurface Carbon Transport and Storage Infrastructure

This subtopic focuses on development of improved materials, system components, sensors or monitoring systems, tools, techniques, and equipment to monitor and/or mitigate internal corrosion within carbon transportation pipelines and subsurface carbon storage wells to ensure the long-term asset integrity and performance of carbon transport and storage infrastructure.

The DOE-FECM's Carbon Transport & Storage Program is focused on further developing and commercializing high Technology Readiness Level (TRL) materials, system components, sensors or monitoring systems, tools, techniques, and equipment that can affordably and effectively be used to monitor and/or mitigate internal corrosion at relevant operating conditions for commercial carbon transport and storage operations. Grant applications are sought to commercialize these things through further development, testing, verification and demonstration across a range of relevant temperatures, pressures, and CO2 conditions. Two technical areas of interest are described below:

- Corrosion mitigation and control tools and techniques including, but not limited to, the use of inhibitors, corrosion resistant materials, internal coatings, and cathodic protection.
- Corrosion measurement and monitoring tools and techniques including, but not limited to, in-place or retrievable sensors, tools, or equipment.

If proposing to test during Phase I at a laboratory-based or pilot-based scale, applicants must describe how laboratory-based or pilot-based testing would demonstrate the efficacy of these corrosion mitigation techniques over a long duration (30+ years of operation) and during typical commercial use (including at commercial scale).

Phase I Projects that progress into SBIR Phase II will be expected to field test their material(s), system component(s), sensor(s) or monitoring system, tool(s), technique(s), or equipment, preferably in a demonstration at a commercial site transporting or injecting supercritical CO2, or at an analog site. At the end of SBIR Phase II, the result of a successful project will be a product(s) ready for commercial application.

Questions – Contact: Paul Zandhuis, Paul.Zandhuis@NETL.DOE.GOV

d. Compact Carbon Capture Technologies

The development of compact carbon capture systems is important in space-constrained applications where Carbon Capture Utilization and Storage (CCUS) is a possible decarbonization approach. Examples of such applications include, but are not limited to, residential and commercial buildings, mobile transportation (heavy duty vehicles and ships), and industrial facilities with limited physical space and emissions from disparate flue-gas streams. Thus, the Point Source Capture Program is supporting the development of compact carbon capture technologies for space-constrained applications.

Applications are sought for designs of compact, preferably modular, carbon capture technologies for space-constrained applications based on equipment, material and process development strategies. These compact systems could incorporate elements including, but not limited to:

- Technologies to enhance mass transfer between liquid absorbent and gas, including the use of rotating spiral contactors, spinning disc reactors (SDRs), spray columns, micro-reactors, membrane gas-solvent contactors and rotating packed beds (RPBs)
- Novel heat integration/regeneration methods to reduce energy requirements associated with the carbon capture process, such as microwave regeneration
- Novel, intensified equipment designs that can integrate several functionalities in one unit (e.g. integrating a reboiler within a RPB desorber unit)

Selected projects will complete a *conceptual design and feasibility study of a compact carbon capture process*. This design will include: (a) process flow diagrams and description of the technology including operating conditions, (b) heat and mass balances of the process, (c) quantification of the reduction in packing volume, footprint, absorber height and regeneration energy relative to state of the art (e.g. conventional packed column), (d) a technology gap analysis for identification of critical elements that need to be further developed and validated, (e) a detailed life cycle analysis (LCA) and (f) a technoeconomic analysis (TEA).
Respondents shall focus their applications on:

- Describing the compact capture system design with material and energy flows in sufficient detail to allow for an evaluation of the proposed concept, including the proposed approach for CO2 capture (sorbents, solvents or others) and CO2 regeneration scheme. Descriptions should also include footprint requirements of the intended application and preliminary calculations to demonstrate space and footprint requirements of the proposed technology.
- Outlining a preliminary life cycle analysis (LCA).
- Outlining a preliminary techno-economic analysis (TEA).
- Limited lab-scale experimentation on the compact carbon capture process to support initial feasibility of the concept.

Questions – Contact: Chet Mun Liew, ChetMun.Liew@netl.doe.gov

e. Techno-economic Feasibility Analysis of CO2 Impurity Removal Processes for Carbon Capture Systems at Industrial or Electric Generation Facilities

Impurities in carbon dioxide (CO2) captured from many point source emissions have the potential to impose significant technoeconomic and environmental challenges for the carbon capture, utilization, and storage (CCUS) value chain. The variety of upstream flue gas compositions, carbon capture methods/approaches, downstream industry operational requirements, and environmental considerations call for case-specific engineering solutions. Therefore, DOE seeks to support innovations in these areas that can significantly improve the cost-performance profile of impurity removal relative to state-of-the-art technologies. Applications are sought to perform techno-economic feasibility studies for conceptual designs of integrated and/or modular CO2 impurity removal systems for carbon capture systems at industrial or electric generation facilities that achieve carbon capture efficiencies of > 95% and CO2 purity of >99 vol%. The proposed integrated and/or modular CO2 impurity removal systems should significantly reduce the cost and/or improve the efficiency of removing impurities in CO2 from a specific point source carbon capture system for a specific CO2 source, relative to state-of-the-art technologies (e.g., cryogenic CO2 distillation ,).

Processes of interest include but are not limited to:

- integrated approaches and/or material/process designs for removing CO2 impurities as a part of the carbon capture system, and
- modular systems to remove impurities downstream of the carbon capture plant.

The CO2 source can include electric generating units or emissions associated with industrial sectors including but are not limited to:

- chemical production (e.g., petrochemicals) excluding ethanol and ammonia production,
- mineral production (e.g., cement and lime),
- pulp and paper production,
- iron and steel production,
- glass production, and
- oil refining (e.g., catalytic cracker, hydrocracking).

Respondents must include the following in the applications:

- description of the target industrial or electric generation process, including specifications for flue gas compositions;
- description of the carbon capture system,
- CO2 offtake purity requirements,
- description of and rationale behind the design of the carbon capture/impurity removal system for achieving the degree of impurity removal, and
- a preliminary technoeconomic analysis (TEA) with key metrics highlighting the proposed technology's advantages relative to state-of-the-art approaches.

The deliverables include:

- impurity removal process flow diagrams and technology description;
- heat and mass balances;
- technology performance and sensitivity analysis towards various ranges of flue gas impurities and limits;
- technology gap analysis to identify critical elements for further development, and
- TEA with cost of CO2 capture, cost of impurity removal, and removal efficiency clearly highlighted, benchmarked against state-of-the-art approaches.

Questions – Contact: Eric Grol, Eric.Grol@NETL.DOE.GOV

f. Lab-scale Testing of Highly Efficient Components to Remove CO2 Impurities for Point Source Carbon Capture

Downstream impurity specifications can potentially require deep removals of impurities in CO_2 captured from point source emissions that are difficult for state-of-the-art carbon capture and purification technologies to achieve. The challenge calls for disruptive impurity removal technologies. The DOE seeks to support lab-scale testing of highly efficient components, including novel materials and processes, that can help condition CO2 for high-purity offtakes.

Applications are sought to perform lab-scale testing of highly efficient novel materials and process technologies that can remove one or more of the following impurities in representative CO_2 streams captured from point source emissions at these specified levels, provided on wet basis: O_2 (<10 ppmv), H_2 (<50 ppmv), CO (<35 ppmv), NO_x (<10 ppmv), SO_x (<10 ppmv), H_2S (< 10 ppmv), and NH_3 (<50 ppmv). Final CO_2 purity should exceed 99 vol%. The proposed project should test the CO_2 impurity removal material or process in a non-integrated, batch operation, with simulated gas representative of the proposed application. It should demonstrate that the proposed CO_2 impurity removal systems can significantly reduce the cost and/or improve the efficiency of removing impurities in CO_2 captured from flue gases, relative to state-of-the-art technologies (e.g., cryogenic CO_2 distillation).

Applications must include the following in the materials:

- description of the target point source emission (industrial/electric) process with flue gas specifications,
- description of the impurity removal technology proposed,
- description of the lab-scale testing and equipment to be utilized,
- description of and rationale behind the design of the impurity removal system, and
- a preliminary technoeconomic analysis (TEA) with key metrics highlighting the proposed technology's advantages relative to state-of-the-art impurity removal approaches.

Questions – Contact: Andy O'Palko, Andrew.Opalko@NETL.DOE.GOV

g. Other

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

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

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2. Baxter, L., Energy-Storing Cryogenic Carbon Capture™ for Utility and Industrial-scale Processes (Final Report) (Technical Report) | OSTI.GOV, https://netl.doe.gov/sites/default/files/netl-file/21AES_Baxter.pdf. (October 29, 2024)

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None.

C60-21. 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

DOE's climate and energy crosscuts enhance collaboration, coordination, and integration across its science and applied energy programs ensure that available resources are focused on achieving the nation's most critical energy and climate challenges. This coordination also helps align the considerable capabilities of DOE's stakeholders, including national laboratories, academia, industry, and other partners.

A major focus in key crosscutting efforts are the launch and execution of Energy Earthshots™ that target the major research, development, and demonstration (RD&D) innovation breakthroughs that must be achieved to solve the climate crisis and reach a net-zero carbon economy by 2050. DOE's Carbon Negative Shot™, one of eight Energy Earthshots™, sets the goal of a portfolio-wide average cost of less than $100/net metric ton of carbon dioxide-equivalent (\$/tCO_2e) removed across carbon dioxide removal (CDR) pathways with gigaton-scale potential inclusive of measurement, monitoring, reporting, and verification (MMRV), robust carbon accounting through cradle-to-grave life cycle analysis (LCA), and secure storage, by 2032. CDR deployment can mitigate ongoing CO_2 emissions from difficult-to-decarbonize sectors (e.g., aviation, shipping, and agriculture) to reduce "net" emissions, as well as to address legacy CO_2 emissions to achieve net-negative emissions goals.

The CDR Program is focused on advancing multiple carbon removal technology pathways and emphasizes methods that minimize removal reversibility and maximize storage duration. CDR R&D is supporting solutions, such as direct air capture (DAC), biomass carbon removal and storage (BiCRS), enhanced mineralization (EM), and marine carbon dioxide removal (mCDR) to remove CO_2 that has accumulated in the atmosphere or enhance the CO_2 uptake potential of bodies of water (e.g., rivers, lakes, and oceans) and durably store it (i.e., geological storage or subsurface mineralization) or convert it into durable 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. Low-Concentration DAC Paired with Ex-Situ Mineralization

Energy needs for DAC of CO_2 from ambient air are driven by the final concentration of the separated CO_2 stream based on the first and second laws of thermodynamics. Many existing DAC systems target concentrations of 95% or higher due to CO_2 transport specifications and requirements for high-purity CO_2 streams for several use cases of CO_2. Achieving such high concentrations of CO_2 from the atmosphere may yield a prohibitive energy cost for some DAC processes.

However, previous work has indicated that it may be possible to integrate a low-purity (5%– 40%) DAC system directly with ex-situ mineralization, using alkaline feedstocks to reduce energy requirements for DAC and thus overall removal costs.

Any energy savings need to be weighed against costs of procuring and processing the alkaline feedstock, as well as any effects on siting and scalability.

Applicants shall focus their applications on:

- Studies to assess the feasibility of integrating low-purity DAC systems with ex-situ mineralization of the captured CO_2 using alkaline feedstocks;
- Lab- and bench-scale R&D to investigate and optimize DAC process parameters that influence performance, cost, and the delivered CO_2 purity;
- Lab- and bench-scale R&D to investigate and optimize ex-situ mineralization process parameters that influence performance, cost, reaction rates, and storage duration;
- Lab- and bench-scale R&D to investigate and optimize key process integration parameters, such as CO_2 purity, temporary low-purity CO_2 storage (as applicable), and different process timescales;
- Development and deployment of MMRV tools and methodologies that account for all associated emissions, energy use, environmental and public health impacts;
- Assessment of supply chains and feedstock availability, final material disposition, scalability, facility siting, and trade-offs among different CO_2 concentrations and alkaline feedstocks; and
- Preparing a preliminary TEA and LCA for the process using the preferred materials and process conditions, incorporating the acquired test data, and centered on evaluating trade-offs and system optimization.

Questions – Contact: Richard (Mike) Bergen, Richard.Bergen@NETL.DOE.GOV

b. Freshwater Alkalinity Enhancement

Ample work within mCDR has focused on increasing the alkalinity of oceans to enable increased uptake of atmospheric CO_2. Ocean alkalinity enhancement (OAE) processes enhance the alkalinity of seawater, thereby increasing the amount of CO_2 that the ocean takes up from the atmosphere to re-establish equilibrium. This can be done in various ways, including direct liquid or mineral addition of alkaline substances to seawater, enhanced mineral weathering, and combined electrochemical or thermal approaches. Several more nascent concepts have focused on manipulating the alkalinity of other bodies of freshwater, such as rivers, the Great Lakes, and pit lakes (including tailing ponds and mining quarries), for CDR.

Applicants shall focus their applications on:

- Assessment of available literature on freshwater alkalinity enhancement, CO_2 injection, or perturbation;

- Lab- and bench-scale R&D to investigate the effects of alkaline feedstock composition, pre-treatment steps, particle size/reactive surface area, and application rate; rainfall; temperature; and freshwater properties on CO_2 removal, with tailored quantification technologies incorporated;
- Lab- and bench-scale R&D (and possibly small field trials) to optimize key process parameters that influence performance, cost, and storage duration;
- Development and deployment of MMRV tools and methodologies that account for all associated emissions, energy use, environmental and public health impacts;
- Assessment of supply chains and feedstock availability, final material disposition, scalability, siting, and trade-offs among different alkaline feedstocks and bodies of freshwater;
- Preparing a Regulatory and Permitting Analysis that discusses all regulatory and permitting requirements, responsible regulatory and permitting authorities, current status, and remaining issues; and
- Preparing a preliminary TEA and LCA for the process using the preferred materials and process conditions, incorporating the acquired test data, and centered on evaluating trade-offs and system optimization.

Questions – Contact: Richard (Michael) Bergen, Richard.Bergen@NETL.DOE.GOV

c. Unconventional BiCRS Pathways

BiCRS pathways are wide ranging and can leverage multiple commonly used biomass feedstocks (woody biomass, algae, agricultural and forestry residues, perennial grasses, etc.), conversion processes (hydrothermal liquefaction, combustion, pyrolysis, torrefaction, gasification, etc.), and terminal storage mechanisms (long-lived bioproducts, geological storage, biochar, bio-oil, etc.) to remove CO_2 from the atmosphere. Biomass feedstocks can also produce a variety of products and coproducts that may displace more carbon intensive incumbent products, reducing emissions alongside carbon removal. Whatever the feedstock, it is important to ensure that it is sustainably sourced and that its use does not deprive from other emissions reduction activities or lead to direct or indirect land use change that offsets net removal. BiCRS processes that utilize unconventional feedstocks, such as fungi, invasive species, food waste, municipal solid waste, sewage sludge, and byproducts from the aquaculture sector, are of interest to the CDR Program as regionality, temporal availability, and preexisting markets for biomass feedstocks require that proposed conversion approaches and storage methods align with proximate resources.

Applicants shall focus their applications on:

- Assessment of available literature on BiCRS pathways that utilize unconventional feedstocks, such as fungi, invasive species, food waste, municipal solid waste, sewage sludge, and byproducts from the aquaculture sector, with a focus on feedstock characterization, harvesting, preprocessing requirements, conversion processes, and terminal storage mechanisms;

- Lab- and bench-scale R&D to investigate the diverse combinations of factors that influence the proposed BiCRS process, including the selection and preparation of sustainably-sourced, unconventional biomass (composition, harvesting, pre-treatment steps, feeding) and environment conditions (temperature, humidity, etc.);
- Lab- and bench-scale R&D of the proposed BiCRS process to optimize key process parameters that influence performance, cost, and storage duration;
- Development and deployment of MMRV tools and methodologies that account for all associated emissions, energy use, environmental and public health impacts;
- Assessment of supply chains and feedstock availability, final material disposition, scalability, siting, and trade-offs among different unconventional biomass feedstocks and net CO_2 removal; and
- Preparing a preliminary TEA and LCA for the process using the preferred materials and process conditions, incorporating the acquired test data, and centered on concerns and considerations related to feedstock materials and associated with counterfactual use cases.

Questions – Contact: Richard (Michael) Bergen, Richard.Bergen@NETL.DOE.GOV

d. **Other**

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

Questions – Contact: Richard (Michael) Bergen, Richard.Bergen@NETL.DOE.GOV

References: Subtopic a:

1. Kelemen, Peter B.; McQueen, Noah; Wilcox, Jennifer; Renforth, Phil; Dipple, Greg; Vankeuren, Amelia Paukert, 2020, “Engineered carbon mineralization in ultramafic rocks for CO_2 removal from air: Review and new insights”, Chemical Geology, 550, https://doi.org/10.1016/j.chemgeo.2020.119628 (October 29, 2024)
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3. https://iopscience.iop.org/article/10.1088/1748-9326/aa6de5 (October 29, 2024)

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1. National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Ocean Studies Board, 2021, Committee on A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration, “A Research Strategy for Ocean-based Carbon

Dioxide Removal and Sequestration", *NIH National Library of Medicine: National Center for Biotechnology Information*. https://www.ncbi.nlm.nih.gov/books/NBK580052/ (October 29, 2024)

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2. Pett-Ridge, Jennifer, Slessarev, Eric W., Schmidt, Briana M., Peridas, George, Pang, Simon H., and Baker, Sarah E., 2022, Initial Considerations for Large-Scale Carbon Removal in the United States. United States: N. p., 2022.https://doi.org/10.2172/1867535(October 29, 2024)

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.

These offices seek grant applications in the following topic areas:

C60-22. 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: NO	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 to monitor for 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 [3] 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. Beta-gamma detector technology improvements

There are several detection methods used for nuclear explosion monitoring: membrane separations, ambient temperature processing, cryogenic cooling [1-5], and cooled charcoal to collect xenon. These monitoring systems concentrate the xenon (including radioxenon) from air and transfer the sample into a nuclear detector. The xenon samples are then typically measured over a 12–24-hour period. All systems used for nuclear explosion monitoring require water and carbon dioxide to be removed from the system prior to xenon collection. State of the art systems use pressure swing adsorption columns filled with aluminum oxide to remove water and carbon dioxide. Pressure swing adsorption requires the columns to reach high pressure during the pressurization step which requires a high-power compressor.

Proposals are sought for a low power water and carbon dioxide removal system that is regenerable, does not require replacement of adsorbent, and can operate on a 100% duty cycle indefinitely. Process gas loss needs to be minimized, as some dryer systems use part of the input gas to regenerate the dryer. Note that exhaust gas from the collection system may be used for regeneration purposes and does not incur sample loss.

Table 1: Water and Carbon Dioxide Removal system.

Requirement	Required	Goal(s)
Power	< 4 W/SLPM of air processed	< 2 W/SLPM of air processed
Dew Point	< -100 deg C	< -120 deg C
CO2 Level	<1 ppm	<.1 ppm

Physical dimensions	No larger than 1 cubic foot total volume	
Environment conditions	Must be able to operate in stable temperature ranges from -10 to 110°F	N/A
Sample gas composition	Air with up to 100% humidity	N/A
Process gas loss	<10%	<2%

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

b. 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 [11]. 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 [6], as with applications of optically pumped magnetometers (OPMs). Quantum measurement for ultra-sensitive detection of acoustic waves is another emerging technology [7] 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 [10]. 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

c. 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 [12], hydroacoustic sensor improvements, or other ways to detect acoustic energy underground [14], on the surface, or in the atmosphere at regional to global distances (>200km) [13]. 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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1. Bowyer, T. W., R. W. Perkins, K. H. Abel, W. K. Hensley, C. W. Hubbard, A. D. McKinnon, M. E. Panisko, P. L. Reeder, R. C. Thompson, and R. A. Warner (1998). Xenon radionuclides, atmospheric: Monitoring in Encyclopedia of Environmental Analysis and Remediation, R. Meyers (Ed.), pp. 5295–5314. New York City: John Wiley & Sons, Encyclopedia of Environmental Analysis and Remediation, Volume 8 | Wiley, (October 29, 2024)
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2. Satzinger, K.J., Y.P. Zhong, HS Chang . *et al.* (2018), "Quantum Control of Surface Acoustic-Wave phonons". *Nature* **563**, 661–665 (2018). DOI: 10.1038/s41586-018-0719-5 (October 29, 2024)

3. Savukov, I. *et al.*, (2017) "High-sensitivity operation of single-beam optically pumped magnetometer in a kHz frequency range." *Measurement Scienceand Technology* 28.3. DOI: 10.1088/1361-6501/aa58b4 (October 29, 2024)
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C60-23. NUCLEAR FORENSICS

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

The Office of Nuclear Detonation Detection (NDD) within the Defense Nuclear Nonproliferation Research and Development (DNN R&D) Office is seeking to improve quantitative separation and detection of rare earth elements (REE) from phosphogypsum and develop a technique to generate unbiased milligram-scale powder samples from heterogenous powders. These technical areas are of interest to nuclear security applications and commercial entities. Grant applications are sought for the following topic areas:

a. High-Purity Separations of Rare Earth Elements from Phosphogypsum

The elemental and isotopic composition of rare earth elements (REE) in phosophogypsum generated from phosphate ore processing [1] are of interest to the nuclear forensics community [2]. Unfortunately, the REEs exhibit nearly identical chemical properties, which present major challenges to interelement separations and quantitative elemental and isotopic characterization [2, 3].

The Office of Nuclear Detonation Detection is soliciting applications to develop advanced separation technologies to quantitatively separate individual REEs from sub-gram samples of phosphogypsum. High separation factors for the individual REEs are needed to support quantitative elemental and isotopic analysis of REEs present in phosphogypsum. Figures of merit to be considered include process time and decontamination factors suitable to support both elemental and isotopic analysis of individual REEs from a single phosphogypsum sample. Processes intended to support industrial separations (>0.5 g of phosphogypsum), not intended to achieve separation factors required for quantitative elemental and isotopic analysis of individual REEs or projects proposing multi-element separations by group (e.g. by 'heavy' and 'light' REEs) will not be considered. Applicants will be responsible for sourcing their own phosphogypsum.

b. Representative Milligram Subsampling of Small Powder Samples

There are several widely recognized procedures for sub-sampling or splitting powder samples [4]. Manual processes such as cone & quartering or scooping are compatible with the nuclear material and radiological safety environment in which nuclear forensics samples are processed. When used on heterogeneous samples these techniques have the potential to introduce sample bias. The best practice for heterogeneous powders where particle size and density vary is to sample when the 'bulk' powder is in motion. Commercial-off-the-shelf (COTS) instruments such as rotary rifflers are available that can produce high quality, representative sub-samples but are designed to process large amounts of material and may not be compatible with the nuclear safety environment in which the samples are processed.

The Office of Nuclear Detonation Detection is soliciting applications to develop powder sampling technologies that can provide single milligram (< 2 mg), unbiased powder samples from sub-gram (<0.5 g) samples of heterogeneous powders and deliver them to substrates suitable for optical imaging, scanning electron microscopy (SEM), secondary ionization mass spectrometry (SIMS) and other analytical techniques. Example substrates include silicon wafers, carbon wafers and gunshot residue (GSR) stubs. Minimizing sample hold-up during sample processing, prevention of background-to-sample and sample-to-sample cross contamination and small footprint (< 0.5 m^2) are critical system characteristics. Any technology employed as part of the sub-sampling process should be compatible with radiological gloveboxes and minimize the use of flammables, combustibles, and high-pressure gases. Applicants will be responsible for sourcing and characterizing their own powders.

Questions – Contact: Richard Gostic, richard.gostic@nnsa.doe.gov

References: Subtopic a:

1. Awad, S., Essam, M., Boukhriss, A. et al.(2024) Properties, Purification, and Applications of Phosphogypsum: A Comprehensive Review Towards Circular Economy. Mater Circ Econ 6, 9 (2024). https://doi.org/10.1007/s42824-024-00100-5 (October 29, 2024)
2. Arrigo, L.M., Jiang, J., Finch, Z.S. et al., 2021,Development of a separation method for rare earth elements using LN resin. J Radioanal Nucl Chem 327, 457–463 (2021). https://doi.org/10.1007/s10967-020-07488-9 (October 29, 2024)
3. Thibault Cheisson, Eric J. Schelter, 2019, Rare earth elements: Mendeleev's bane, modern marvels. Science 363,489-493(2019), DOI: 10.1126/science.aau762, Rare earth elements: Mendeleev's bane, modern marvels | Science(October 29, 2024)

References: Subtopic b:

1. Jillavenkatesa, A., Lum, L. and Dapkunas, S. (2001), NIST Recommended Practice Guide: Particle Size Characterization, Special Publication (NIST SP), National Institute of Standards and Technology, Gaithersburg, [5] MD, [online], https://doi.org/10.6028/NBS.SP.960-1 (October 29, 2024)
2. K.J. Moody, I.D. Hutcheon & P.M. Grant,2005, *Nuclear Forensic Analysis*. Boca Raton, FL. CRC Press. https://doi.org/10.1201/9780203507803 (October 29, 2024)

C60-24. 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: NO	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 multimodal data fusion, multimodal foundation model training, and dynamic AI system develop to develop approaches for aligning foundation models with scientific disciplines, concepts, and goals. Grant applications are sought in the following subtopics:

a. Experimentation framework for secure federated learning-as-a-service (FLaaS)

A secure federated learning as a service (FLaaS) capability is needed that can be deployed in hybrid architectures that may include edge devices, on-premises high performance computing and data storage, and FedRAMP High commercial cloud-based data storage and compute. This capability must support essential workflows for machine learning in nuclear nonproliferation applications, including data ingestion, model training, evaluation, and deployment in a distributed and secure manner. The solution must incorporate data privacy-preserving techniques and ensure compliance with FedRAMP High security requirements while allowing the integration of multimodal data sources such as satellite imagery, text reports, and sensor data. The secure FLaaS platform must enable federated data preprocessing, ensuring that local data remains at the edge or on-premises while allowing centralized model training across distributed nodes. Key workflows include model aggregation, model evaluation, and feedback loops for continuous improvement in detecting nuclear proliferation risks. The platform must also facilitate continuous learning by updating models in near-real time as new data becomes available, enhancing detection capabilities through multimodal foundation models that integrate text, image, and signal data streams. Proposals must demonstrate the ability to create a scalable, secure architecture that supports collaborative learning among stakeholders while maintaining the confidentiality of sensitive data sources.

b. Other

In addition to the technologies listed in subtopic a., grant applications in relevant technologies that can meet the objective of subtopic a. are also invited.

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. https://doi.org/10.48550/arXiv.2307.01139 (October 29, 2024)
2. Burke, L., et al. 2023, Dynamically Persistent Remote Inference of Nuclear Facility Activity: Challenges and Approach.*PNNL*, https://resources.inmm.org/sites/default/files/2023-07/finalpaper_400_0512070555.pdf
3. NukeLM, 2022, https://github.com/pnnl/NUKELM (October 29, 2024)

C60-25. RADIATION DETECTION MATERIALS

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

The Office of Proliferation Detection 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. Large-volume, high-performance, room-temperature operational CdZnTe (CZT) semiconductor gamma-ray detectors

The mission to detect, characterize and identify illicit nuclear materials, would benefit from commercial availability of gamma-ray detectors capable of high energy resolution and higher detection efficiency. Current room-temperature gamma-ray detectors are not capable of achieving high-resolution (of HPGe) gamma-ray spectroscopy and high sensitivity (of NaI) simultaneously, which is necessary for the identification and characterization of special nuclear materials. Over the past three decades, significant progress has been made in the development of CZT gamma-ray spectrometers and imagers. Compact CZT detectors having a total detection volume of 19 – 29 cm^3 and energy resolution better than 1.0% FWHM at 662-keV have been commercialized, using multiple 4 – 6-cm^3 single-crystal CZTs [1]. However, larger single-crystals are desired for higher photopeak efficiency at higher gamma-ray energies, better coded aperture gamma-ray imaging performance, and potential lower cost on detector fabrication and assembly.

The Defense Nuclear Non-proliferation R&D Office of Proliferation Detection is soliciting the development of high-resolution (better than 1.0% FWHM at 662-keV) CZT semiconductor gamma-ray detectors with single-crystal detection volume equal to or larger than 24-cm^3. The development includes the advancement to improve yield of high performance CZT single crystals, detector fabrication and assembly processes, position sensitive ASIC readout technologies that can correct signal variations as a function of gamma-ray interaction position and operational temperature in a wide range of temperatures from -20°C to +50°C. The desired CZT materials cost is less than $1000/cc (threshold) and less than $500/cc (objective). Development will also lead to the commercialization of larger volume CZT detectors for higher detection efficiency at higher gamma-ray energies, including to better understand the commercial availability and yield of these larger CZT detectors, and to improve the performance of large CZT detectors using signal correction techniques for material non-uniformity and position dependent signal induction properties.

Questions – Contact: Dr. Hank Zhu, 202-586-1874, hank.zhu@nnsa.doe.gov

b. Other

In addition to the technologies listed in subtopic a., grant applications in relevant technologies that can meet the objective of subtopic a. are also invited.

Questions – Contact: Dr. Hank Zhu, 202-586-1874, hank.zhu@nnsa.doe.gov

References:

1. Yuefeng Zhu, et al., “Performance of Larger-Volume 40 x 40 x 10- and 40 x 40 x 15-mm^3 CdZnTe Detectors” IEEE Transactions on Nuclear Science. PP. 250-255, Vol. 68, No. 2, February 2021, Selective Hydrogenation over Supported Metal Catalysts: From Nanoparticles to Single Atoms | Chemical Reviews (October 29, 2024)

C60-26. X-RAY IMAGING PANEL 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: NO	Accepting STTR Fast-Track Applications: NO

The Office of Proliferation Detection within Defense Nuclear Nonproliferation Research and Development (DNN R&D) has an objective to improve field radiography diagnostics for emergency responders using high energy radiography (HER) sources ranging to 7-MeV peak energy. The office is interested in developing next-generation high efficiency digital radiography (DR) flat panel detector technologies to support this application. Grant applications are sought in the following subtopics:

a. High Efficiency Digital Radiographic Imaging Panel

Current DR panels are repurposed commercial off the shelf (COTS) medical panels that are typically tuned to 50-keV peak energy. These systems are currently used with HER sources with greatly reduced efficiency (0.3%-1% efficiency) which results in low signal to noise ratios (SNR), demand for brighter sources, and increased integration time. COTS non-destructive testing (NDT) panels using internal intensifier screens and scintillator doping have been investigated by the emergency response community but have not met cost and design requirements to replace the entirety of the current deployed capability.

The emergency response community is seeking to take advantage of recent and promising high efficiency scintillator technologies such as gadolinium lutetium oxide (GLO), $CsPbBr_3$ perovskites, and metal grated plastics such as PVT with tungsten that are significantly thicker than current deployed scintillators ranging from 300-400 µm. The desired community requirements are outlined below [1].

PARAMETER		Current Specs	REQUIREMENT Threshold (Minimum)	Desire (Ideal)	Priority	Why
Performance	Efficiency at Peak Energy	Tuned for 50 keV peak energy	2% efficiency at 7 MeV peak energy	≥5% efficiency at 7 MeV peak energy	H	Higher SNR, lower integration time, reduced RGD output requirement and wear.
	Shielding	.1-1mm lead or equivalent	.25mm lead or equivalent	1mm lead or equivalent	M	Reduce backscatter from high energy x-rays and improve SNR
	Intensifier/filter	None	.1mm lead or equivalent Single layer useable with low and high energy.	Dual Use, low energy and high energy reversible sides.	M	Increased contrast and efficiency for high energy while capable of dual use with low energy
	Pixel Pitch	150 μm	150 μm or hardware binned equivalent	200 μm or hardware binned equivalent	H	Optimized light collection with useable resolution
	Fill Factor	~75%	75%	≥75%	M	Maximize useable area of pixel size and minimize loss of spatial resolution.
	Frame Rate	?	.03-1 Hz capable of synching with pulsed generator	.03-32 Hz capable of synching with pulsed generator	M	Synchronization with pulsed generators to increase SNR.
	Dynamic Range	16 bit	16 bit	≥16 bit	M	Contrast to Noise Ratio

PARAMETER		Current Specs	REQUIREMENT Threshold (Minimum)	Desire (Ideal)	Priority	Why
SWaP	Size (Panel)	36cm x 43cm active area	Standard Format: 30cm x 30cm Large Format: 60cm x 60cm	Standard Format: 36cm x 43cm Large Format: 72cm x 90cm	H	Portable
	Weight (Panel)	~10 lbs.	Standard Format: 15 lbs Large Format: 50 lbs.	Standard Format: 20 lbs Large Format: 50 lbs.	M	
	Size (container)	not specified	minimal size needed to protect and store panel, batteries, and charger	minimal size needed to protect and store panel, batteries, and charger	M	
	Weight (container)	not specified	Standard Format: 30 lbs Large Format: 70 lbs.	Standard Format: 35 lbs Large Format: 70 lbs.	M	
	Battery life	~90 minutes (+hot swap)	~90 minutes	~120 minutes (+hot swap)	M	Enough for mission
Operation	Operating Conditions	not specified	1. Temperature: -7C to 40C 2. Humidity: 80% @ 25C 3. Pressure: 745-775 mm Hg	1. Temperature: -20C to 55C with active cooling system. 2. Humidity: 80% @ 25C 3. Pressure: 730-790 mm Hg	M	Image quality in field conditions.
	Thermal Stability	No	Use reflective white surface	Active cooling	M	
	Connectivity	Ethernet/WiFi	Ethernet with standard connectors/NO WiFi	Ethernet with standard connectors/NO WiFi	M	Standardize connectivity without wireless option
	IP rating	not specified	IP65 rated	IP67 rated	H	Environment protection
	Onboard Storage	Yes	Only calibration files. No image or customer data storage	No non-volatile RAM	M	Security
	Drop Rating	1 meter drop test	1 meter	2 meter	M	damage prevention
User Interface	XTK integration	Yes	XTK integration	XTK integration with unified scan control	H	Integration with current deployed software
	Summation	Yes, unified control	None. XTK managed	User controlled realtime summing of images in unified scan control	M	User controlled variables based on image need
	Averaging	Yes, unified control	None. XTK managed	User controlled realtime averaging of images in unified scan control	M	
	User defined hardware Binning	No	None. XTK managed	User defined binning of pixels (2x2, 3x3) in unified scan control	M	
	Subtraction	Yes, unified control	None. XTK managed	XTK integration with unified scan control	M	
	Calibration	Dark field only	Flat, both Dark and Bright field, with bad pixel map	Flat, both Dark and Bright field, with access to raw files and all raw images with bad pixel map	M	
Other	Lifetime	not specified	5 years	10 years	M	life cycle
	Cumulative Dose	100 kRAD	100 kRAD	200 kRAD	M	
	Supply chain	not specified	Global (Non-Adversarial)	Domestic	L	Maintainability
	Regulatory rqmts	not specified	minimal requirements	All applicable	M	Operational licensing

XTK = X-Ray Toolkit software developed and managed by Sandia National Laboratories

The phase I project must specify intended design specifications meeting end user performance requirements. The panel design must also be economically viable. Phase I results must produce estimates of specific end user requirements and leveraged technology. Phase II will include the manufacture, testing and integration of prototype panels and lead to immediately available products for emergency response evaluation. Preference will be given to solutions which address supply chain challenges including lead-times and availability of domestically manufactured components.

b. Other

In addition to the technologies listed in subtopic a., grant applications in relevant technologies that can meet the objective of subtopic a. are also invited.

Questions – Contact: Dr. Hank Zhu, 202-586-1874, hank.zhu@nnsa.doe.gov

References:

US NRC, 2024, Digital Field Radiography Operational Requirements, Office of Nuclear Incidence Response (NA-84), National Nuclear Security Administration, 2024, Nuclear Emergency Support Team (NEST) | Department of Energy (October 29, 2024)

C60-27. 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: NO	Accepting STTR Fast-Track Applications: NO

The Office of Proliferation Detection 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. Accelerators for Industrial Radiation Processing

Industrial irradiation facilities expose a wide variety of products to ionizing radiation, including medical devices, spices and other food, cosmetics, and plastics. The desired effects are the eradication of pathogens, food preservation and safety, pest control, and material property modification. Large scale industrial sterilization facilities can contain millions of curies of Co-60 (IAEA Category 1), a small fraction of which could be used in an act of radiological terrorism [1]. While electron beam and x-ray system development has dramatically improved in recent years, users still note a need for a lower-cost system with high-resiliency to handle extended or continuous operation in domestic and international locations under a wide variety of electrical and environmental conditions [2,3].

The Office of Proliferation Detection is soliciting the development of a cost-effective, robust, and high-efficiency electron accelerator for industrial radiation processing applications. The accelerator must be particularly reliable to avoid costly downtime for industrial radiation processing operations, particularly in environments with inconsistent utility access. High beam-power and high electrical-efficiency are required for the accelerator to be economically and operationally competitive with Co-60-based contract sterilization. Alternatively, a compact, lower power, lower cost accelerator that could be more easily distributed than Co-60 facilities or even incorporated into current product manufacturing or treatment processes is also a desirable approach. The electron beam is expected to be above 5-MeV, and system flexibility to easily convert to x-ray operation is desirable to allow effective treatment of thick or dense products.

b. Novel Approaches to Accelerator Component Redesign and Domestic Manufacturing

A key mission of the NNSA 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. In the 2021 National Academies of Sciences (NAS) report on Radioactive Sources: Applications and Alternative Technologies, [4] 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 lack of domestic manufacturing base for critical accelerator components.

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, and for whom few commercial manufacturers exist. RF systems remain in short supply and may require six-months to a year for delivery after an order is placed. Other key 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 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; and 3) enabling reliable maintenance.

c. 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: Dr. Hank Zhu, 202-586-1874, hank.zhu@nnsa.doe.gov

References:

1. National Research Council, National Academies of Science, "Radiation Source Use and Replacement," National Academies Press, Washington, D.C., 2008, Radiation Source Use and Replacement: Abbreviated Version | The National Academies Press (October 29, 2024)

2. International Atomic Energy Agency, 2008, “Trends in Radiation Sterilization of Health Care Products,” Vienna, Austria, 2008. http://www-pub.iaea.org/MTCD/publications/PDF/Pub1313_web.pdf. (October 29, 2024)
3. P. Dethier, 2016, "Industrial Gamma and X-ray: ‘Same but Different’," IBA Industrial, https://www.iba-industrial.com/white-papers/ (October 29, 2024).
4. National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies, 2021, Nuclear and Radiation Studies Board; Committee on Radioactive Sources: Applications and Alternative Technologies. Radioactive Sources: Applications and Alternative Technologies. Washington (DC): National Academies Press (US); 2021 Jun 14. PMID: 34524768. Radioactive Sources: Applications and Alternative Technologies | The National Academies Press (October 29, 2024)

C60-28. 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: NO	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 and 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. Enhanced photomultiplier base technologies for data readout.

In large neutrino/antineutrino detectors data readout equipment represents a large portion of the experimental footprint in both cost and physical size [1-3]. Research of interest will include projects that seek to build photomultiplier (PMT) readout devices/base technology that can operate at lower power than current systems, provide higher value/cost ratio than current commercial waveform digitizers and high-voltage mainframe systems. The system must have flexible programmable readout for dynamic triggering. Systems may take advantage of machine learning/artificial intelligence and neuromorphic technologies to enhance analysis for phenomenology like pulse shape discrimination and or other high speed signal processing to increase efficiency in signal processing (e.g. reduction in output data volume or increased signal throughput).

b. Demonstration or analysis of Mie-tronic systems for spectroscopic collection.

Spectroscopy has been a useful tool for remote sensing in the nuclear nonproliferation arena [4,5]. Current research instruments span a wide range of wavelengths and sensitivities to the spectral region of interest. A research direction of interest to this office is the development of more compact systems with broadly tunable sensitivity that can be achieved by the application of the physics of Mie resonances that allow efficient spatial and temporal control of light [6,7]. Demonstration and/or analysis of novel light sources or detector focal planes that enhance spectroscopic collection and analysis in multiple environments from Earth to the Moon are items of interest.

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 [8]. The nuclear nonproliferation community has an interest in ensuring the safe deployment and use of such vessels which can be effected via remote sensing [9]. Hyperspectral imagery is one remote sensing technology that can be implemented to assist nuclear power monitoring agencies for surface and subsurface environments [10]. Hyperspectral imagery data collected over bodies of water present unique analysis challenges [11]. 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. T. Anderson et al. Eos: conceptual design for a demonstrator of hybrid optical detector technology, 2023 JINST 18(02) P02009. DOI: 10.1088/1748-0221/18/02/P02009.
2. Yongbo Huang, Jinfan Chang, Yaping Cheng, Zhang Chen, Jun Hu, Xiaolu Ji, Fei Li, Jin Li, Qiuju Li, Xin Qian, Soeren Jetter, Wei Wang, Zheng Wang, Yu Xu, Zeyuan Yu,The Flash ADC system and PMT waveform reconstruction for the Daya Bay experiment, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 895, 2018, Pages 48-55, ISSN 0168-9002, https://doi.org/10.1016/j.nima.2018.03.061.

3. Abi, B., R. Acciarri, M. A. Acero, M. Adamowski, C. Adams, D. Adams, P. Adamson et al. "The DUNE far detector interim design report volume 1: physics, technology and strategies." arXiv preprint arXiv:1807.10334, https://arxiv.org/abs/1807.10334 (2018).

References: Subtopic b:

1. Pozzi, S.A., He, Z., Hutchinson, J. et al. Detecting and characterizing special nuclear material for nuclear nonproliferation applications. Sci Rep 13, 10432 (2023). https://doi.org/10.1038/s41598-023-36171-8.
2. Dawn M Levy, Simultaneous detection of uranium isotopes and fluorine advances nuclear nonproliferation monitoring (2024, September 26) retrieved 11 October 2024 from https://phys.org/news/2024-09-simultaneous uranium-isotopes-fluorine-advances.html.
3. Yuri Kivshar, The Rise of Mie-tronics, Nano Letters 2022 22 (9), 3513-3515, DOI: 10.1021/acs.nanolett.2c00548, https://pubs.acs.org/doi/10.1021/acs.nanolett.2c00548 (2022)
4. Won, R. Into the 'Mie-tronic' era. Nat. Photonics 13, 585–587 (2019). https://doi.org/10.1038/s41566-019-0512-5, https://www.researchgate.net/publication/335372686_Into_the_'Mie-tronic'_era (August 2019)

References: Subtopic c:

1. "Putting the Blue back in Red, White and Blue - Decarbonisation of the US maritime industry with advanced nuclear", Dr Rory Megginson, Tony Huston. CORE POWER(UK) Ltd., https://www.corepower.energy/resources/reports (2022)
2. "Living up to the Hype of Hyperspectral Aquatic Remote Sensing: Science, Resources and Outlook", Heidi M. Dierssen, Steven G. Ackleson, Karen E. Joyce, Erin L. Hestir, Alexandre Castagna, Samantha Lavender, and Margaret A. McManus. Frontiers in Environmental Science, Vol. 9, Article 649528, https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2021.649528/full (June 2021)
3. "Hyperspectral 3D Mapping of Underwater Environments", Maxime Ferrera, Aur élien Arnaubec, Klemen Isteni ˇc, Nuno Gracias, Touria Bajjouk, Conference: 2021 IEEE/CVF International Conference on Computer Vision Workshops (ICCVW), https://arxiv.org/abs/2110.06571 (October 2021)
4. "Detection of underwater objects in hyperspectral imagery," D. B. Gillis, 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://www.researchgate.net/publication/320662521_Detection_of_underwater_objects_in_hyperspectral_imagery (August 2016)

PROGRAM AREA OVERVIEW – OFFICE OF NUCLEAR ENERGY

The primary mission of the Department of Energy (DOE), Office of Nuclear Energy (NE) is to advance nuclear energy 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) Keep existing U.S. nuclear reactors operating.
(2) Deploy new nuclear reactors.
(3) Secure and sustain our nuclear fuel cycles.
(4) Expand international nuclear energy cooperation.

NE strives to promote integrated and collaborative research under the direction of NE's programs, and to deploy innovative nuclear energy technologies to the market and to optimize the benefits of nuclear energy

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 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.

C60-29. 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 systems. This topic addresses several key areas that support the development of crosscutting capabilities, reactor sustainability, advanced reactor technologies, 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. 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.

DOE is seeking applications for collaborative small business partnerships 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 NDE 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

d. 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 for collaborative small business partnerships 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

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.

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

Advanced versions of liquid metal 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. Specifically, DOE is interested in applications focused on the development of roller bearings for use in refueling systems – both radial, thrust, and combined radial and thrust bearings are of interest. 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. Reactor Plant Co-Pilot for Advanced Liquid Metal Reactors

Advanced Reactors will benefit from the installation of software that will support advanced reactor startup, operations at power, and shutdown. These advanced reactors will have a combination of digital and some analog controls with sensors for monitoring the performance of the reactors. It is expected that the number of sensors will be increased over what the current fleet of reactors have. In addition, small and micro-reactors will require the assistance of software to support the operations of multiple reactors connected to the grid while reducing the head count per reactor.

Thus, for advanced reactors there is a need for a piece of software that will perform the following functions:

- Gather sensor data from the plant.

- Monitor the status of the components and equipment in the plant.
- Compare the component and equipment status with expected status of the plant given the plant operating mode.
- Provide anticipatory guidance to the plant operator if sensors are drifting out of normal expected range.
- Based upon the physics of the plant, provide information on temperatures, pressures, flowrates, and other data at locations where no sensor exists (i.e., a virtual sensor).
- The Co-Pilot software will have the ability to incorporate all operations and emergency procedures into its software to provide instructions to an operator on operating the reactor plant.
- The Co-Pilot software will have the ability to incorporate necessary information from the documented safety analysis report and PRA to ensure that the plant is staying within its safety basis documentation.
- The Co-Pilot software will be able to be trained on plant data.
- The Co-Pilot software shall have an application programming interface for integration with external applications.
- Natural language processing so that operators know why the algorithm is recommending a certain action.
- Emulating/testing capabilities.
- Security features such as single sign-on, MFA-multiple methods, connection to active directory
- For plants that are crediting inherent safety, the physics-based Co-Pilot software will operate in the background, gather sensor and virtual sensor data, and analyze the data to ensure that the plant's inherent safety posture is always met.
- The software needs to be scalable and demonstratable on a non-nuclear test facility, such as a liquid metal test facility.

DOE is seeking applications for development of this Reactor Plant Co-Pilot software for use in advanced reactors. Applications should focus on liquid metal reactors, recognizing that the proposed software could be broadly applicable to additional advanced reactor concepts.

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

h. Oxygen Sensors for Sodium Service

There is a need to restart the development of the electrochemical oxygen meter for service in liquid sodium as delineated in NE Standard (formally RDT) – NE C 8-5T. The meter shall provide a continuation indication of the oxygen impurity concentration over the range of 0.5 to 20ppm oxygen in sodium at a temperature between 700 and 800F. The in-sodium oxygen sensor shall be designed and tested. Its design shall be such that the failure of the sensor will not insert debris into the coolant stream or create a source of a sodium leak. The in-sodium oxygen sensor will be designed to meet the specifications of the NE Standard. Ideally, the electrochemical oxygen meter will work in sodium, sodium-potassium alloy, lead, lead-bismuth eutectic, and molten salts with perhaps changes in the materials of construction.

DOE is seeking applications to develop these sodium service oxygen sensors that meet NE Standard – NE C 8-5T (please contact Kaatrin Abbott for a copy of the Standard, if needed.

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

i. Heat Pipe Heat Exchanger

Supercritical CO2 Brayton power cycles show great promise in microreactor applications, specifically for designing novel supercritical CO2 primary heat exchangers for heat pipe reactors. A continual impediment to implementation of the sCO2 Brayton power cycle is the primary heater. A direct heat pipe to sCO2 heat exchanger would be the simplest arrangement, but due to the high temperatures and pressures of the sCO2 working fluid the design of this heat exchanger becomes challenging.

DOE is seeking applications from a U.S. company or companies to design a direct heat pipe to sCO2 heat exchanger to foster growth for U.S. industry.

Potential areas of collaboration include but are not limited to:

- Design of a primary heat exchanger for heat pipe reactors using sCO2 technology
- Experimental validation testing of a prototype heat exchanger using an sCO2 flow loop
- Full integration of a prototype sCO2 power block with electrically heated heat pipe simulator.

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

j. High Speed Power Electronics

Supercritical CO2 Brayton power cycles show great promise in microreactor applications, specifically for designing high speed (excess of 40,000 rpm) permanent magnet rotors that allow for optimal design conditions of the rotating components for sCO2 compression and expansion. However, it is presently difficult to procure suitable power electronics to control the permanent magnet rotor at high speed and high power. DOE is seeking applications from U.S. companies to advance the state of the art for high-speed power electronics for power levels exceeding 300kW and rotor speeds capable of 75,000 RPM.

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

k. High Temperature Supercritical CO2 Seals

The increasing demand for microreactors demonstrates the need for power conversion systems less than 10MWe. At these power levels, the rotational speeds are more than 40,000 rpm and high temperature seals are needed to support power conversion equipment utilizing supercritical CO2 Brayton power conversion cycles. DOE is seeking novel designs to seal axial shafts at 700C and 4500 psi to support the commercialization of sCO2 Brayton cycles.

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

l. Development of Ancillary Technologies Supporting Molten Salt Reactor (MSR) Deployment

DOE is seeking proposals from qualified entities to research, develop, and demonstrate innovative technologies that will support the deployment of MSRs. This funding opportunity aims to accelerate the commercialization of MSR technologies, enhance their operation efficiency and address technical and regulatory challenges.

MSRs are a promising class of advanced nuclear reactors with potential to provide safe, reliable, low-carbon energy. They offer several benefits including high thermal efficiency, inherent safety features, and the ability to use various fuel sources. The research, development, demonstration, and deployment of MSRs depend on the commercialization of many ancillary technologies at lower technology readiness levels for high temperature molten salt applications. Potential technologies include, but are not limited to:

- Molten salt compatible components (valves, pumps, gaskets, heat exchangers, actuators, etc.)
- Molten salt compatible sensors (reference electrodes, radiation sensors, property measurements, etc.)
- Supply chain (salt synthesis, salt purification, isotope enrichment, salt recycling, transportation and storage, etc.)
- Radionuclide management (medical isotope extraction, noble gas capture, tritium capture, filtration, etc.

Questions – Contact Michael Stoddard, Michael.stoddard@nuclear.energy.gov

m. 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 and 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 that have no compromise in durability and robustness of designs. Cost is one of the fundamental drivers for enabling commercialization of technologies.

Proposed projects must 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 must 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 must 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 or the cost and integration of nuclear e-fuel plants with nuclear reactors:

<u>Reactor and Auxiliary Component Costs</u>—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 research and development (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.

<u>Reactor Installation Costs</u>—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.

Nuclear E-fuel Plant and Integration Costs – Proposed projects will develop a reference cost-representative plan for the on-site construction and installation of Nuclear E-fuel Production technologies with connections necessary for nuclear plant integration. It is expected that proposed projects will document a detailed reference design that focuses on the production of synthetic diesel, gasoline or jet fuel based on reference designs for capturing and purifying carbon dioxide from concentrated sources, powering water electrolysis system, and chemically converting carbon dioxide and hydrogen into product fuels with methanol routes, producing CO with co-electrolysis or reverse water-gas shift rectors, or reactions that produce methanol directly from CO2. The manufacturing 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. The methods for construction and installation will be developed in detail to establish the cost to install an integrated nuclear system for nuclear e-fuel synthesis. The construction and installation costs 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

n. Fuel Synthesis Reactors for Nuclear E-fuels

Several promising routes have been identified by DOE to address the hard to decarbonize industrial and transportation applications. There are several carbon-neutral nuclear e-fuels pathways to produce synthetic fuels with nuclear reactors as the primary energy source. These include routes that produce methanol as an intermediate chemical, or Fischer Tropsche based processes.

DOE seeks to develop designs that will lead to fabrication of a thermally integrated open-architecture reactor system to convert syngas (CO and H2) into synthetic diesel, gasoline or jet fuels. This architecture will be used to test and identify the durability, throughput, efficiency, and selectivity of commercially producible low-cost catalysts capable of low-cost fuels production, where a source of pure CO2 and Hydrogen already exists. The system should consider the feedstock, product, and heat transport required for thermal integration and testing at 1 to 2 barrels of product per day, scales required for determining the feasibility of large-scale commercial systems.

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

o. Advanced and Small Reactor Physical Security Cost Reduction

For advanced and small nuclear reactors to be competitive with other electrical generation sources, they will need 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: Dan Warner, daniel.warner@nuclear.energy.gov

p. Advanced and Small Reactor Material Control and Accounting (MC&A) 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 MC&A requirements for future advanced and small nuclear reactors. Additional information on MC&A work already completed through the NE Advanced Reactor Safeguards Program can be found at energy.sandia.gov/ars.

Questions – Contact: Dan Warner, daniel.warner@nuclear.energy.gov

q. 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: Dan Warner, daniel.warner@nuclear.energy.gov

r. 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 for CAS operators, in possible partnership with a company or university with a strong human factors' component, to integrate their 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: Dan Warner, daniel.warner@nuclear.energy.gov

s. 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 (LWR) 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 environment and energy security. Technology should demonstrate and support improved functionality and efficiencies in plant operations and maintenance. This will include improvements to support functions, such as security, management, administration, procurement, and radiation protection. Effective modernization requires improved process automation, machine intelligence and computer aided decision making.

To achieve this mission in the nuclear power industry, applications are sought in one of the following plant modernization areas:

- Artificial intelligence/machine learning technologies are sought for troubleshooting and diagnosing nuclear plant operational problems to improve the timeliness and effectiveness of response to emergent degraded conditions. These technologies must enable significant savings in engineering and technical support costs while addressing model explainability concerns. These technologies must 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: Sujata Goetz, Sujata.Goetz@nuclear.energy.gov

t. Software Development for Digital Instrumentation Control (DI&C) System Risk Assessment and Design Optimization

DI&C systems at nuclear power plants (NPPs) have been proven to be more reliable, cheaper, and easier to maintain given obsolescence of analog components. However, they also pose new engineering and technical challenges including the potential common cause failures (CCFs) unique to safety-critical DI&C systems. Adding diversity within a system or components is the main means to eliminate and mitigate CCFs, but diversity also increases plant complexity and errors, and may not address all sources of systematic failures. How to optimize the diversity and redundancy for safety-critical DI&C systems remains a challenge.

The DI&C Assessment project within the Risk-Informed Systems Analysis (RISA) pathway of the Light Water Reactor Sustainability (LWRS) program has developed an integrated risk assessment framework to support vendors and utilities with optimization of design solutions from economical perspectives while still achieving risk-informed safety requirements. This integrated risk assessment framework includes both qualitative hazard analysis and quantitative reliability and consequence analysis for addressing software CCF in the safety-critical DI&C system. It offers a capability of design architecture evaluation of various DI&C systems to support system design decisions and diversity and redundancy applications.

Applications are sought for the development of a common and a modularized software platform for DI&C designers, software developers, cybersecurity analysts, and plant engineers to efficiently predict risk and reduce cost in the early design stage of DI&C systems. This software platform should be able to process and transfer quantitative and qualitative data to realize the comprehensive capabilities of the integrated framework including (1) identifying software failures in the unit-level interactions inside of a digital system, (2) quantifying software failure probabilities based on suitable software reliability methods, and (3) integrating with probabilistic risk assessment and cost analysis models. A user-friendly interface should be designed to reduce the difficulty and complexity in the application of the comprehensive framework. Sufficient and concise information should be provided to users to support DI&C system risk assessment and design optimization.

Questions – Contact: Sujata Goetz, Sujata.Goetz@nuclear.energy.gov

u. 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 SMR 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

v. 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 construction project management, digital engineering, open architecture design, construction technologies, manufacturing approaches, etc. Proposed 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

w. Supporting Technologies for Microreactor Operations

NE 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 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.

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

x. 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.
- Environmental conditions such as temperature, humidity, and pressure, present in nuclear plants including the conditions found in helium cooled and liquid metal cooled reactors.

The application must 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

y. 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: Diana Li, Diana.Li@nuclear.energy.gov

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

Nondestructive examination (NDE) techniques for in-situ monitoring of cable insulation are an important component of aging management and sustainable operation of the U.S. 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 de-energized and often require cables to be disconnected from their circuits. The ability to monitor cable condition on-line (continuously during operation) or without disconnecting and de-energizing the cables could greatly reduce the time and expense associated with cable monitoring. In addition to cost savings, these technologies have the potential to improve operational safety and maintenance efficiency through continuous monitoring or larger cable fractions to be examined each outage cycle.

Examples of possible methods include:

- Fiber optics for distributed temperature sensing of component local environments.
- On-line spread spectrum time domain reflectometry for circuit health monitoring.
- On-line FDR (frequency domain reflectometry) or JTFDR (joint time-frequency domain

- reflectometry).
- On-line partial discharge testing for low/medium voltage cables.

Questions – Contact: Sue Lesica, sue.lesica@nuclear.energy.gov

aa. 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

bb. 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

cc. Filtration of solid particulates suspended in molten salt solutions

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. Insoluble oxide and metallic particulates scan form and accumulate in molten salt solutions during synthesis, operation, post-operation treatment as a result of several different phenomena including corrosion, reactions with contaminants in the cover gas, and production of insoluble fission products. Although improvements in synthesis, operation, and treatment should decrease particulate formation, molten salt filtration technology will still be necessary for optimal performance of molten salt systems and for recovery from off normal conditions. Applicants should refer to published studies of particulate formation in molten chloride and molten fluoride systems for guidance on temperature, particulate size, and composition.

Questions – Contact James Willit, james.willit@nuclear.energy.gov

dd. 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

ee. 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.go

ff. Recovery and purification of NO2 for reuse

Proposals are sought for technologies that would allow the separate recovery of purified NO2 and H2O from a gas stream that contains NO2, H2O, O2, Kr, Xe, Ar.

The goal is the recovery for reuse of NO2 and the recovery of tritiated water.

Questions – Contact: Bill Del Cul, bill.delcul@nuclear.energy.gov

gg. Production of Zr metal by direct electroreduction of ZrCl4 in molten salt

Proposals are sought for an electroreduction process that would allow the direct electroreduction of ZrCl4 to Zr metal with a coarse morphology that would be non-pyrophoric.

The goal is to directly produce metallic Zr in a non-pyrophoric form from ZrCl4 as a raw material to produce Zr alloys.

Questions – Contact: Bill Del Cul, bill.delcul@nuclear.energy.gov

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

Improvements and advances are wanted for the fabrication and design on nuclear reactor fuel. Advanced technologies are sought that will enable development and economic deployment of advanced nuclear reactor fuels including water, sodium, or gas reactor applications.

- Provide new innovative accident tolerant LWR fuel cladding/assembly concepts that have the potential to support achieving enhanced safety and performance capable fuel that are significant improvements over what is currently being pursued. Cooperation is strongly encouraged with a national laboratory 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.

- Develop and/or improve characterization methods for Tri-structural ISOtropic particle fuel (TRISO) coated particle fuels that are applicable to fuel fabrication and quality control or to post-irradiation examination   Capabilities of interest include advanced methods for quality assurance/quality control image analysis techniques, NDE and X-ray tomography including automated data analysis, AI techniques, and automated NDE for fuel particle and compact property evaluation. Cooperation is encouraged with DOE national laboratories and/or other TRISO fuel fabrication companies with fuel fabrication and characterization capabilities or companies that manufacture current TRISO characterization measurement equipment (e.g., X-ray tomography, anisotropy, and mercury porosimeter), since use of prototypic samples for device or methodology development would be required.

Grant applications may use non-fueled surrogate materials to simulate uranium, plutonium, and minor actinide bearing fuel. Compromises associated with surrogates must be clearly addressed.

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

ii. 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

C60-30. 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 Office of Spent Fuel and High-Level Waste Disposition (SFWD) and its three sub-program offices: the Office of Disposal R&D, the Office of Storage & Transportation, and the Office of Consent-Based Siting, are developing an Integrated Waste Management system for storage, transportation, and disposal of spent nuclear fuel and high-level radioactive waste.

Grant applications are sought only in the following subtopics:

a. 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.
- 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. The application of artificial intelligence, machine learning, and generative AI to collect, process, analyze data and make predictions where appropriate, is welcomed. 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: John Orchard, John.Orchard@nuclear.energy.gov

b. Novel Materials and Manufacturing Methods for Impact Limiters

The transport of the nation's spent nuclear fuel (SNF) and high-level radioactive waste (HLW) is expected to be conducted by freight rail. During transportation, Normal Form (or Type B) packaging includes freight rail containers encased in structures called impact limiters, which protect the package and its contents in the event of an accident. In addition to meeting U.S. Nuclear Regulatory Commission (NRC) regulations for spent fuel shipping containers, impact limiters are a key transportation package component for the safe transport of SNF and HLW.

Impact limiters consist of a metal shell filled with energy-absorbing materials. Different materials have been used over the years, including plastic foams and metal honeycombs, with wood being a commonly used material. During an accident, impact limiters function by being crushed and absorbing impact forces. The materials encased in the shell are therefore crucial for the proper function of impact limiters. The large-scale transportation of more than 90,000 metric tons SNF from existing light water nuclear reactors to one or more federal consolidated interim storage facilities will require dozens of Type B packaging sets of casks and impact limiters. The long-term use of wood, such as old growth redwood and/or balsa wood, in impact limiters is not sustainable (e.g., environmental impact, supply limitations).

Furthering the NE mission to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs, research and development on novel materials and manufacturing methods (which may include 3D printing) to be used as Type B impact limiters are sought. NE is particularly interested in integrated research projects supporting the efficient and cost-effective fabrication of impact limiters that 1) meet NRC certification requirements in 10 CFR Part 71 and 2) use manufactured materials (and not natural materials, such as wood).

Questions – Contact: Jay Thomas, jay.thomas@nuclear.energy.gov

C60-31. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY CROSS CUTTING CAPABILITIES

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: YES

New methods and technologies are needed to address key challenges affecting the future deployment of nuclear energy systems. This topic addresses the development of crosscutting capabilities.

Grant applications are sought in the following subtopics:

a. 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

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.

C60-32. 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 electric power grid is facing increasing stress due to fundamental changes in both supply-side and demand-side technologies. 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 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.

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, security, and affordability will remain a top priority as aging infrastructure and changing demand, supply, and market structures create new operational challenges.

In addition to the requirements listed in each subtopic, each applications to this topic must:

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

Grant applications are sought in the following subtopics:

a. Cutting-edge Microgrid Database Development with Artificial Intelligence/Machine Learning/Big Data Analytics through SBIR Innovations

Microgrid systems are increasingly being relied upon to provide reliable power for critical infrastructure (e.g. data centers), commercial and industrial (C&I) enterprises, residential communities, and military installations. Microgrids are also being leveraged to service remote and isolated communities that often do not have dependable access to the traditional grid. In general, microgrids are becoming the solution of choice for entities seeking decentralized energy independence, and to improve the reliability, resiliency, and affordability of their electricity supply. Furthermore, microgrids provide structural means to optimize the aggregation and utilization of distributed energy resources (DERs) to service both local energy needs and grid resilience functions. FERC Order 2222[30], which aims to enable DERs aggregators to participate on the wholesale electricity market, is set to transform the architecture of the grid edge as well as electrical distribution system planning, operation, control and management. Microgrid systems will play a pivotal role in the implementation of this Order.

However, different sectors (e.g. residential, C&I, etc.) face multiple obstacles with microgrid deployment, and tackling these obstacles will require: a) identifying reliable technical and cost/benefits data for microgrid project implementation; b) mapping pathways to quantify the value of reliability, affordability and resiliency for microgrid systems; and d) developing and communicating lessons-learned and best-practices from successfully deployed microgrids. The identification and definition of metrics that support the quantification of these aspects will be possible with the analysis of data sourced by a robust, and well-structured publicly or commercially available state-of-the-art microgrid database. Most importantly, stakeholders represented by industry and government, must rely on innovative technological tools that enable the support of decision-making processes for potential investment on microgrids. These decisions can benefit significantly from the use of modern databases that provide an optimized variety of descriptive, system-level variables. However, and unfortunately, there is a lack of reliable sources with up-to-date data/information on already deployed microgrids in the US territory that can showcase the number of variables needed for a one step ahead analysis. A robust, state-of-the-art microgrid database can be significantly helpful to enable tracking the key variables linked with existing microgrid operations and serve as an objective proxy for highlighting the benefits that these systems deliver to communities and in general to the end users.

The objective of this SBIR subtopic is small business innovative design of state-of-the-art microgrid database, amenable to AI (Artificial Intelligence)/ML (Machine Learning)-based Big Data analytics, to support data extraction that enables robust stakeholder decision-making around microgrid planning, design, operations and maintenance. The use of AI/ML for advanced analytics will support the identification and extraction of key trends and information, which can help inform stakeholder or end-user decision-making activities. A state-of-the-art microgrid database, amenable to AI/ML Big Data analytics techniques, stimulates technological innovation and constitutes a powerful tool for stakeholders, as it serves as a convenient source of organized information relating to microgrid characteristics, as well as microgrid technical and economic performance. Furthermore, the utilization of a state-of-the-art microgrid database will provide policy makers, investors, utilities, and other potential end-users with structured and optimized informational support that would

[30] FERC Order No. 2222: Fact Sheet; September 2020; https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet

aid cost/benefit analysis, planning, and decision-making relating to microgrid deployment considerations. The database is intended to provide much more than just a comprehensive listing of operational microgrid installations. The data provided by the database can help mitigate the information as well as perceptional barriers facing more widespread microgrid deployment.

Strong proposals will successfully articulate a robust approach for tackling this challenge and satisfy the following criteria (at a minimum):

- Database oriented toward industry end-users to increase market commercialization of innovations and private sector adoption of microgrids.
- The database should track the following non-exhaustive list of variables - microgrid location, capacity in kW or MW, voltage level, AC, DC or hybrid, type of load/profile, cost of the project/investment, cost of operation/LCOE, grid connected or Islanded, storage capacity, types of distributed generation, type of control subsystem (type of controller), topology, metrics to evaluate operation/reliability/resiliency, type of ownership, flexibility of the microgrid to add resources (i.e. expansion of load, expansion in generation), networked or non-networked, main grid configuration, lessons learned, among others.
- Leverage AI/ML Big Data techniques to support the identification of valuable patterns and relationships within large datasets that otherwise will remain hidden.
- Incorporate innovative means for capturing the site, installation and other context-specific variables while also providing anonymity where needed or requested for microgrid owners or information providers.

Questions – Contact: Dr. Roxana Melendez, roxana.melendez@hq.doe.gov

b. Risk and Uncertainty Visualization Tools for the Electric Grid Decision-Making

The escalating complexity of modern power grids —characterized by increased interdependencies, shifts in demand trends, and increased penetration of intermittent renewable energy sources and distributed assets, coupled with the growing uncertainty associated with extreme weather and climate events— have significantly elevated the stakes of effective decision-making. Moreover, the recent explosion of 'big data' has facilitated the development of advanced data-driven models, providing invaluable insights for managing the sustainability, resilience, reliability, and security of the grid. However, the efficacy of these data-informed models is inherently limited by the veracity, volume, velocity, and spatiotemporal limitations of the underlying data.

Balancing supply and demand under deep uncertainties—related to policy, technology, data availability, and climate patterns— is a formidable task. Moreover, the emergence of prosumers, who can both generate and consume electricity, coupled with diminished utilities' visibility at the grid edge further complicates the grid's muti-sectoral operational landscape.

Utilities and investors systematically confront deep uncertainties, knowing that suboptimal decisions can have far-reaching consequences, including grid instability, economic losses, and compromised grid reliability and resilience. To mitigate these risks, it is imperative to have access to assessments and visualization of underlying uncertainties in multi-sector complex systems. Moreover, transparent communication of 'assumption deviations', resulting from discrepancies between model assumptions and real-world conditions, can build trust between modelers and decision-makers. By explicitly characterizing and communicating the sensitivity of risk analyses to various sources of uncertainties and assumptions, energy sector decision-makers can better understand the potential limitations of their analyses and make more informed choices. Understanding the sensitivity of model outputs to underlying assumptions and uncertainties is essential for enabling grid operators to make informed choices and ensure the continued resilience and reliability of the power system

This subtopic aims to advance the state of practice in multi-sector risk analysis that enables reflecting and visualizing various types of uncertainty and assessing the sensitivity of model outputs to underlying assumptions for more effective decision-making by grid operators and planners.

Successful projects would accelerate commercial development and deployment of methods and tools that can enable any of the following capabilities for the electricity sector stakeholders, including utilities, regulators, and system planners.

- Multi-sector uncertainty visualization to assist with energy sector decision-making related to planning, operating, and coordinating grid resources.
- Clear representation, visualization, and/or communication of different types of uncertainty (i.e., epistemic vs aleatory[4]) related to various phases of risk analysis including risk maps of undesirable scenarios and associated consequences.
- Clear analytics, representation, and/or visualization of the sensitivities of risk models' outputs to underlying model assumptions.
- Human-factors and cognitive science informed decision processes that incorporate information trust and quality

Questions – Contact: Dr. Roshi Nateghi, roshanak.nateghi@hq.doe.gov

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2. FERC Order No. 2222: Fact Sheet; September 2020; https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet (October 29, 2024)
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C60-33. DC-LINK CAPACITORLESS VOLTAGE SOURCE CONVERTERS FOR GRID-TIED 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 numerous technical and economic benefits for the future electric utility grid. They enhance the value of renewable energy sources, such as photovoltaic systems and wind energy, by offering flexibility for customers, maintaining power quality, increasing asset utilization, and deferring the need for grid upgrades. Ultimately, grid-tied energy storage systems improve the reliability, security, quality, flexibility, and cost-effectiveness of both existing and future electric utility infrastructures.

A crucial enabling technology for energy storage is the power conversion system (PCS), also known as power electronics. In a grid-tied energy storage system, the PCS manages the power flow to and from the grid, optimizing the performance of the energy storage devices while maintaining grid stability. The primary electrical components of a PCS include semiconductor switches, magnetic devices such as inductors and transformers, capacitors, and a controller.

In recent years, wide bandgap (WBG) semiconductor devices have garnered significant interest due to their superior characteristics compared to traditional silicon semiconductor switches. These advantages include higher breakdown voltage, faster switching speeds, and higher junction temperatures. WBG devices are pivotal for the development of future high-efficiency, high-density power converters, which are essential for both alternative power generation and energy storage systems.

Grant applications are sought in the following subtopic:

a. Advanced DC-Link Capacitorless Voltage Source Converters for Next Generation Battery Energy Storage Systems (Long Duration Storage Shot Topic)

The most common method for connecting stationary energy storage systems to the grid involves using a two-level voltage source converter (VSC) with a DC-link capacitor and a DC-DC converter between the energy storage technology and the VSC. These capacitors, which can be made from aluminum electrolytic, film, or ceramic materials, serve to stabilize the DC voltage by limiting fluctuations when the inverter intermittently demands heavy current. These capacitors also impact the overall cost, reliability, and power density of the power conversion system. However, they are prone to failure due to various intrinsic and extrinsic factors, including design defects, material degradation, operating temperatures, voltage and current stresses, moisture, and mechanical stress.

We are seeking applicants to develop a wide bandgap-based, DC-link *capacitorless*, three-phase voltage source converter with a power rating exceeding 10 kW, a DC-link voltage greater than 800 V, and a 480 V AC output. The final design should demonstrate significant improvements in performance, cost reduction, and a smaller footprint compared to traditional grid-tied power conversion systems.

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

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