ENERGYTECH UNIVERSITY PRIZE

2022 OFFICIAL RULES DOCUMENT

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WELCOME TO THE ENERGYTECH UNIVERSITY PRIZE

Welcome to the U.S. Department of Energy Office of Technology Transitions EnergyTech University Prize (EnergyTech UP)!

In EnergyTech UP, student teams will compete for a total of $259,500 in cash prizes for successfully identifying a promising energy technology, assessing its market potential, and creating a business plan for commercialization.

EnergyTech UP aims to cultivate the next generation of energy innovators while accelerating the transfer of energy technologies to the market. This prize seeks to attract the talented students of today and help them develop into the engineers, policymakers, entrepreneurs, market analysts, and project developers of tomorrow. Multidisciplinary student teams will develop and present a business plan that leverages national laboratory-developed or other high-potential energy technologies.

This prize is sponsored by the Office of Technology Transitions (OTT) at the U.S. Department of Energy (DOE), as well as the Geothermal Technologies Office, Solar Energy Technologies Office, Office of Nuclear Energy, Office of Fossil Energy and Carbon Management, Building Technologies Office, and Water Power Technologies Office.

EnergyTech UP, in partnership with American-Made Challenges, is designed to be approachable, equitable, and scalable nationwide. Winners will be chosen based on the strength of their proposal, not the strength of the team's background.

DOE's EnergyTech UP will be governed by this Official Rules document. The Prize Administrator, the National Renewable Energy Laboratory (NREL), and DOE reserve the right to modify this Official Rules document if necessary and will publicly post any such modifications as well as notifying prize competitors of a revised document.

This prize program consists of three phases, the Explore Phase, the Refine Phase, and the Pitch Phase, as summarized in Figure 1.

Figure 1: Phases of EnergyTech UP

Explore Phase

In the Explore Phase competitor teams will present their ideas at one of the regional events. Competitors will submit a 200-word statement describing their proposed technology and associated business plan. Teams will then be invited to participate in a regional event.

Regional Prizes

Regional Winners: At the conclusion of the Explore Phase, the Regional Winner from each of the regional events will be awarded $2,500 and invited to the Refine and Pitch Phases. A maximum of $27,500 total will be awarded to Regional Winners.

The Regional Winners will move on to the national competition to compete for the National Prize as well as any relevant bonus prizes. Each region will select a single winner who will move forward. In addition, each region may select up to six separate teams for further consideration as Technology Bonus Prize Semifinalists.

Technology Bonus Prize Semifinalists: Each regional convener may also identify up to six (6) Technology Bonus Prize Semifinalists (up to one for each technology bonus prize category).

From the pool of all Technology Bonus Prize Semifinalists across all Explore Events, a single Technology Bonus Prize Finalist per technology category will be selected *after* the conclusion of the Explore Events. Selection will be based on materials submitted at the regional Explore Events. Up to six teams will be awarded $2,000 and invited to the compete in the Refine and Pitch Phases alongside the Regional Winners. A maximum of $12,000 total will be awarded to Technology Bonus Prize Finalists.

Refine Phase

In the Refine Phase, Regional Winners and Technology Bonus Prize Finalists will be provided exclusive mentorship and free access to OTT's Energy I-Corps curriculum to help them refine their ideas throughout March.

Regional Winners and Technology Bonus Prize Finalists will be paired with a mentor or mentors from industry, a national lab, or the Department of Energy. Mentors will give competitors insights into technology development and feedback on their business plan in preparation for their presentation during the national Pitch Phase event. Competitors are also encouraged to explore the Other Relevant Programs and Opportunities described below during this phase.

Pitch Phase

The Regional Winners and Technology Bonus Prize Finalists will pitch their refined business plans at Carnegie Mellon University Energy Week in March 2022. This event may be in-person or virtual, depending on the state of the COVID pandemic.

National Prizes

National Winners: The National First-Place Winner will be awarded $50,000, the National Second-Place Winner will be awarded $15,000, and the National Third-Place Winner will be awarded $5,000. A total of $70,000 in National Prizes will be awarded.

Technology Bonus Prizes: Six (6) Technology Bonus Prizes of $25,000 each may be awarded to teams who participate in the national Pitch Phase event. The focus areas of each Technology Bonus Prize are provided in Table 7.

Additional program information is available at www.energy.gov/energytechup. Questions should be submitted to ott.energytechup@nrel.gov.

ABOUT THE OFFICE OF TECHNOLOGY TRANSITIONS

This prize is primarily sponsored by DOE's Office of Technology Transitions (OTT). DOE's primary mission is to ensure America's security and prosperity by addressing its energy, environmental, and nuclear challenges through transformative science and technology solutions. These solutions have given rise to a diverse range of technologies, from the superconducting magnets that enabled Magnetic Resonance Imaging (MRI) to the battery cathodes that are used in today's plug-in electric vehicles.

World-changing innovations like these become possible only by transitioning technology out of the laboratory and into the commercial sphere. But it's almost never easy—so in 2015, the Secretary of Energy authorized the formation of OTT, and in 2020, Congress formalized its establishment.

OTT serves as the steward of DOE's Research, Development, Demonstration and Deployment (RDD&D) continuum and is sponsoring this prize to aid technologies in their progression to commercialization. More information about OTT can be found at https://www.energy.gov/technologytransitions/office-technology-transitions.

SUMMARY OF IMPORTANT DATES

For the exact dates and latest information, visit www.herox.com/energytechup/timeline.

October 4, 2021: Program Announcement Date

October 20, 2021, 3 p.m. ET: Informational Webinar

- Watch a recording of our informational webinar.

January 31, 5 p.m. ET: Explore Phase Submissions Close

- Teams submit a 200-word summary of the technology to be leveraged and the business opportunity, along with an initial slide deck, and indicate their region of choice.
- Teams will be invited to present at a regional convener Explore Phase event.

February 2022: Regional Convener Explore Events

- Exact dates and times to be determined; these will be different for each region.
- Teams pitch business plans.
- One winner from each regional convener Explore Phase event will be selected; winners will receive $2,500 and will advance to the national competition.

March 2022: Refine Phase

- Regional winning teams receive mentorship and access to Energy I-Corps curriculum to improve their business plans.

Mid-March, 2022: Pitch Phase Submission Due

- Regional winning teams submit their written business plan, slide deck, and a short video presentation.

March 24, 2022: Pitch Phase Event

- Regional winning teams present to a panel of industry judges as part of Carnegie Mellon University's Energy Week.

March 24, 2022, 5 p.m. ET: National and Technology Bonus Prize Winners Announced

ELIGIBILITY

- All participating students must be enrolled in an accredited collegiate institution. Students must be enrolled in at least one class and must be pursuing a degree throughout the duration of the competition.
    - For the purposes of this competition, "collegiate institution" refers to a school of post-secondary or higher education, including but not limited to community colleges, colleges, universities, and graduate schools.
    - Post-secondary students of any level are eligible to compete.
    - Students will self-certify their eligibility as part of registration for the competition.
    - Teams with students from multiple collegiate institutions are allowed, and multiple teams from the same collegiate institution are allowed. Individual students may be members of only one team.
- Teams must consist of at least two collegiate students, with a single student identified as team captain.
- The team captain must be a U.S. citizen or permanent resident.
- The final submission must come from the team captain's HeroX account.
- The team may have non-student team members or advisors who provide input and guidance and support the development of the idea, but only students may present to judges, and student team members must be a majority of the team makeup.
- Members of the expert reviewer panels, competition administrator staff, national laboratory employees, and DOE employees are ineligible to compete.

- Immediate family members of DOE employees and NREL Prize administrators are ineligible to compete.
- To be eligible to compete in the Pitch Phase event, the team must be selected as a regional Explore Phase winner.
- By uploading a submission package, the team self-certifies that it is compliant with the eligibility requirements. If the competition administrator becomes aware that a team or individual is not eligible, that team may be disqualified from competition.

TECHNOLOGY AREAS OF INTEREST

Submissions must focus on technologies that produce energy, store energy, improve the efficiency of consumption or transmission, or increase the security and reliability of energy systems.

Six DOE Technology Offices are offering up to $25,000 each in technology bonus prizes for the best teams in their respective fields. The six offices include the Geothermal Technologies Office, Solar Energy Technologies Office, Office of Nuclear Energy, Office of Fossil Energy and Carbon Management, Building Technologies Office, and Water Power Technologies Office.

Teams searching for a technology to build a business plan around are encouraged to engage with the Lab Partnering Service described below.

DOE recognizes that primary energy sources take many forms, including nuclear energy; fossil energy like oil, coal, and natural gas; and renewable sources like wind, solar, geothermal, and hydropower. These primary sources are converted to electricity, a secondary energy source, which flows through power lines and other transmission infrastructure to homes and businesses.

Keeping power flowing to American homes and businesses is a necessity for everyday life and economic vitality. DOE works to keep the grid secure from cyber and physical attacks, partners with states and other stakeholders to plan more weather-resilient infrastructure, and works to increase grid efficiency and energy storage capacity as more renewable energy sources come online.

Teams may focus their submissions on technologies developed at a national laboratory or on technologies developed by other entities. Teams are not required to have secured a license or rights to a technology in order to present a business plan that leverages a specific technology, but they should have confidence that the technology could hypothetically be licensed or otherwise be made available to a team for use as part of their business model.

DIVERSITY, EQUITY, AND INCLUSION

It is the policy of the Biden Administration that:

> The Federal Government should pursue a comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality. Affirmatively advancing equity, civil rights, racial justice, and equal opportunity is the responsibility of the whole of our Government. Because advancing equity requires a systematic approach to embedding fairness in decision-making processes, executive

departments and agencies (agencies) must recognize and work to redress inequities in their policies and programs that serve as barriers to equal opportunity.

By advancing equity across the Federal Government, we can create opportunities for the improvement of communities that have been historically underserved, which benefits everyone.[1]

As part of this whole-of-government approach, this competition seeks submissions that will benefit members of disadvantaged communities and underrepresented groups. Teams are highly encouraged to include individuals from groups historically underrepresented in science, technology, engineering, and mathematics (STEM) on their project teams. Teams are also highly encouraged to develop business plans that would benefit disadvantaged communities and/or underrepresented groups.

Further, in an effort to remove barriers to entry for all team members, judging criteria are established to determine success based on the quality of the proposal, not the quality of the team's resumes or prior experience.

OTHER RELEVANT PROGRAMS AND OPPORTUNITIES

In addition to EnergyTech UP, DOE funds several related programs that may provide additional value, context, or guidance to competitors. Participants are encouraged to learn more about each program as they develop their ideas or to consider follow-on opportunities.

Lab Partnering Service

In support of EnergyTech UP, a custom "popular topic" tab has been created that highlights technology summaries, experts, facilities, and success stories that may be of particular interest to competitors. Teams that are interested in participating in this contest but have yet to identify a technology to focus on should use this service to explore potential technologies.

OTT's Lab Partnering Service (LPS) is a free online service that gives investors, innovators, and institutions direct access to the vast array of expertise, research, and capabilities present across all 17 national labs and three sites. LPS serves as a generation tool for partnering with DOE labs. LPS allows users to submit inquiries to the Technology Transfer Office at each lab based on the lab profile, technology summaries, experts, and facilities. However, any technology indicated on the LPS is eligible for consideration as part of the program.

LPS also has a tool called the Visual Patent Search (VPS). This search tool enables a unique, visually facilitated search of the patent content contained in the LPS. This patent content consists of published U.S. patent applications and issued U.S. patents resulting from DOE-funded research and development (R&D), as well as a portion of patents from NASA and the Department of Homeland Security. The patents are pulled from the United States Patent and Trademark Office patent database and show patents and patent applications from the last 20 years.

[1] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-advancing-racial-equity-and-support-for-underserved-communities-through-the-federal-government/

LPS can be found at www.labpartnering.org, and VPS can be found at https://vps.labworks.org/. The LPS page developed to support the EnergyTech UP prize can be found at https://energytechup.labpartnering.org/.

Energy I-Corps

Energy I-Corps, a key initiative of OTT, pairs teams of researchers with industry mentors for an intensive two-month training where the researchers define technology value propositions, conduct customer discovery interviews, and develop viable market pathways for their technologies. Researchers return to their home institutions with a framework for industry engagement to guide future research and inform a culture of market awareness within the labs. In this way, Energy I-Corps is ensuring our investment in the national labs is maintaining and strengthening U.S. competitiveness long-term.

Winners of the Explore Phase will receive access to Energy I-Corps curriculum and associated materials for all team members that are typically available only to national lab researchers.

American-Made Network

The American-Made Network provides entrepreneurs with connections to help them succeed. The network is a collective made up of more than 100 technology incubators and accelerators, venture capital firms, angel investors, and industry representatives. Energy entrepreneurs can tap into the industry expertise and resources across the network to help accelerate the development and commercialization of their new ideas and products.

Competitors are encouraged to visit the American-Made Network and explore resources that are available to support their efforts in this prize and beyond.

Technology Commercialization Fund

A core responsibility of OTT is implementing the Technology Commercialization Fund (TCF) authorized in section 1001 of the Energy Policy Act of 2005. Competitors are encouraged to review previous TCF awards for inspiration and to consider TCF funding as a funding mechanism as a possibility in any business plan developed.

The TCF is a nearly $30 million funding opportunity that leverages R&D funding in the applied energy programs to mature promising energy technologies.

The goal of the TCF is twofold. First, it is designed to increase the number of energy technologies developed at DOE's national labs that graduate to commercial development and achieve commercial impact. Second, the TCF will enhance the Department of Energy's technology transitions system with a forward-looking and competitive approach to lab-industry partnerships.

Energy Program for Innovation Clusters

The DOE Energy Program for Innovation Clusters (EPIC) is a two-part program sponsored by OTT to encourage the robust growth of regional energy innovation ecosystems across the United States. Competitors of EnergyTech UP should consider reaching out to winners of the EPIC program for possible synergies.

With EPIC, OTT funds local innovation clusters, which increase the productivity of area companies, drive the direction and pace of innovation, and stimulate the formation of new businesses.

The first part of EPIC was the prize portion, which awarded a collective total of $1 million to 20 incubators focused on developing strong regional innovation clusters. To learn more about our selected winners, head to the EPIC prize winner blog series here.

The second part was a funding opportunity announcement (FOA) that sought to recognize innovation-accelerating organizations focused on stimulating energy hardware development and related supportive ecosystems. In June 2021, DOE awarded $9.5 million to 10 incubators and accelerators across the country as part of the EPIC FOA. Learn more about the winning projects here.

Summer Entrepreneurship Program

The annual OTT Summer Entrepreneurship Program is an exciting internship opportunity for undergraduate students looking to experience DOE's world-class national lab system, boost entrepreneurial thinking, and explore market opportunities. Competitors of EnergyTech UP should consider applying to this internship program.

OTT Entrepreneurship Program details include the following:

- The program is a 10-week internship that pairs students with technologies and mentors from the DOE national labs to develop strategies for commercialization.
- Students undergo intensive training to understand and advance cutting edge technologies in fields spanning machine learning and artificial intelligence, computing, data science, biofuels, energy, materials, and more.
- Parallel to this technical training, the students also undergo intensive training in commercialization through Energy I-Corps curriculum.
- At the end of the program, students present their individual work and also pair into teams to create and deliver investor pitches, which are judged by a panel of experts in technology commercialization.
- The program benefits participants by enhancing their education and training in entrepreneurship and energy technology-related fields and increasing their future marketability in these disciplines.

PRIZES TO WIN

Explore Phase

At the conclusion of the Explore Phase, each of the winning teams from the regional events will be awarded $2,500. A total maximum of $27,500 will be awarded.

At the conclusion of the Explore Phase, all semifinalists for each Technology Bonus Prize will be evaluated based on the materials submitted at the regional Explore Event. One team in each Technology Bonus Prize area will be identified as a finalist, awarded $2,000, and invited to participate in the Pitch Phase. A maximum of $12,000 will be awarded for these Technology Bonus Prize Finalists.

Pitch Phase

At the conclusion of the Pitch Phase, DOE will award three National Prizes and six Technology Bonus Prizes.

National Prizes

National Winners: The National First-Place Winner will be awarded $50,000, the National Second-Place Winner will be awarded $15,000, and the National Third-Place Winner will be awarded $5,000. A total of $70,000 in national prizes will be awarded.

Technology Bonus Prizes: Six (6) Technology Bonus Prizes of $25,000 each may be awarded to teams who participate in the national Pitch Phase event. The focus areas of each Technology Bonus Prize are provided in Table 7.

A single team may win both a National Prize and a Technology Bonus Prize, a single prize in either category, or no prize at all.

How To Enter

EnergyTech UP will utilize the HeroX website as its competition platform. This platform empowers people to create, compete in, and share contests that address and solve global problems.

Go to https://www.herox.com/EnergyTechUP and follow the instructions for registering and submitting all required materials before the deadlines identified in the Summary of Important Dates section. Deadlines are also displayed on the HeroX website.

1. Go to the competition page at https://www.herox.com/EnergyTechUP.
2. Create a HeroX account if you do not already have one, including activating your account by clicking the verification link sent to your email. Then, sign in and choose "Solve this Challenge." You will need to accept the Competitor Agreement to get started. This indicates your interest in competing; it is not a commitment to compete.
3. If you know the email addresses of your team members, or if you are joining an already established team, you can enter information when prompted. If your team makeup is not yet known, you will have an opportunity to add other team members later. You can continue to adjust your team composition throughout the competition.
4. By the registration deadline, the team captain must click "Begin Entry," fill out the necessary form items, then choose "Save & Preview." The team captain must then click "Submit Final Entry" on HeroX to complete the team's registration. This step is when the team identifies their collegiate institution (community college, college, university, or graduate school) and expected team makeup. There is no cost to submit a registration entry. Note that you can edit and resubmit your entry as many times as you would like up until the registration deadline.
5. Select the appropriate region for your team. If there is a regional convener in the same state as the team captain's collegiate institution, the team must select that regional convener. If there is not, select the closest regional convener geographically.
6. Registration entries received by the deadline are deemed applicant teams.
7. Multiple teams from a single school may compete.
8. Teams may have students from multiple schools.

9. Only one person per team should submit a "team" registration. Other members can join the registered team via HeroX. Team members may be added or removed from a team at any time. Once you have registered a team, you can invite additional members using HeroX.
10. Following registration, the Prize Administrators will review all registrations and may re-allocate teams across regional conveners to ensure an appropriate and fair competition.
11. Email questions to the organizers at ott.energytechup@nrel.gov.

REGIONAL CONVENER EXPLORE EVENTS

EnergyTech UP applicant teams will be invited to attend and compete at one of the regional convener Explore Phase events that will be held across the United States. These events aim to provide a rich experience for participants, allowing participants to engage in networking opportunities and attend other team and professional presentations. Each team is expected to have at least one student present at the regional convener Explore Phase event. If a team has a faculty or industry advisor, the advisor is also encouraged to attend the Explore Phase event. While it will be up to each regional convener to determine if an Explore Phase event will occur with in-person components or entirely virtually, all events will enable teams to present remotely. It will be the responsibility of the regional convener to utilize the 200-word summary and initial slide deck provided as part of the registration to determine which teams will be invited to present. Each regional convener will have the ability to host at least 15 teams but may accommodate up to 30, at their discretion. The capacity will be clearly stated before January 15, 2022.

If there is a regional convener in the same state as the team captain's collegiate institution, the team must select that regional convener. If there is not a regional convener in the same state as the team captain's collegiate institution, the team must select the closest one geographically.

The following regions and locations are confirmed:

Table 1: Regions for Explore Phase Events

Region	Location
Appalachia and South	Lexington, Kentucky
California	San Diego, California
Carolinas	Raleigh, North Carolina
Great Lakes	Chicago, Illinois
Mid-Atlantic	Pittsburgh, Pennsylvania
New York Tri-State Area	New York City, New York
Northeast	Somerville, Massachusetts
Northern Plains	Minneapolis, Minnesota
Southeast	Central Florida
Texas	Houston, Texas
West	Tucson, Arizona

Faculty, non-student team members, and industry advisors may not participate in the team presentation. The organizers will not provide financial assistance for lodging and/or travel expenses to teams for the regional convener Explore Phase events, but virtual participation will be available.

NATIONAL PITCH EVENT

Regional Winners and Technology Bonus Prize Finalists will present their business plan to industry judges on Thursday, March 24, 2022, as part of CMU Energy Week 2022. Students will receive free access to the entire CMU Energy Week program.

Hosted by Carnegie Mellon University's Wilton E. Scott Institute for Energy Innovation, CMU Energy Week 2022 will take place from Monday, March 21 - Friday, March 25. Attendees will receive access to informative sessions designed to engage thought leadership on critically important topics for our nation's energy and innovation future.

WHAT TO SUBMIT

Explore Phase

- A 200-word written summary addressing the energy technology to be leveraged and the business opportunity.
- A slide deck that summarizes your business plan, including the suggested content identified in Table 3.

Pitch Phase

- A written business plan that addresses the suggested content identified in Table 5 and optionally in Table 7.
- An up to 90 second video demonstrating the technology to be leveraged and the business opportunity.
- A slide deck that summarizes your business plan, including the suggested content identified in Table 5 and optionally in Table 7.

HOW EXPLORE PHASE WINNERS ARE DETERMINED

The regional convener will identify and secure a panel of judges to witness the Explore Phase presentations. Winners will be announced as part of the Explore Phase event, and within 30 days following the announcement, the Prize Administrator will work with winners to collect the necessary information to distribute cash prizes.

How Regional Judges Score the Explore Phase

A panel of judges, chosen independently by regional conveners, will evaluate the teams using the statements given in Table 3. Immediately following the conclusion of the Explore Phase presentations, judges will meet to determine which team will advance to the Refine Phase. Scores will not be shared with any of the teams. Only the Regional Winner and Technology Bonus Prize Semifinalists will be determined and announced. Each bullet listed in the Explore Phase evaluation statements receives a score from 1 to 6. Teams will be judged based on the extent to which the judging panel agrees with the evaluation statements according to the scale shown in Table 2.

Table 2: Scoring Scale

1	2	3	4	5	6
Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree

Explore Phase Content and Evaluation Statements

For the Explore Phase, teams will present an initial business idea that leverages a national lab-developed or other promising energy technology. Teams will be given 5–10 minutes to present their technology and business plan. The final presentation format and allotted time to be provided by each regional convener will be described on HeroX. The team should have a clear understanding of the technology and its commercialization potential, the existing market, and a plan for commercializing their chosen technology. The judging panel will evaluate the teams using the evaluation statements in Table 3.

A panel of expert judges will read, score, and comment on each submission. The bullets have equal weight, so categories that have more review criteria bullets have a greater influence on the final score. The final score from an individual judge for a submission package equals the sum of the scores for all the bullets. All judges' scores are then averaged for a final score for the submission package. The regional judging panel will consider individual scores when deciding the Regional Winner and Technology Bonus Prize Semifinalists for their Explore Event.

This prize seeks to encourage inclusivity and diversity, commercialization of national lab tech, and the pursuit of a broad mix of technologies. Before making the final awards, judges will assess the portfolio against these dimensions. The final determination of winners will take reviewer scores, team presentation performance, reviewer deliberation, and program policy factors listed in the Additional Terms and Conditions into account.

Table 3: Explore Phase Content and Evaluation Statements

1. Technology Identification	
Suggested Content: A. What is the energy technology to be leveraged?	Evaluation Statements: A. The team deeply understands their technology of choice and explained it clearly.
2. Market Assessment	
Suggested Content: A. Who will buy the product or service and why do they need it? B. Who is currently serving this market and how? C. What unmet market need will this technology help to fill?	Evaluation Statements: A. The team deeply understands the range of potential customers for their identified technology, including what pain points this technology might solve for the customer. B. The team evaluation of the relevant market was comprehensive and included all potential competitors. C. The team has clearly identified a sizeable unmet market need.
3. Economic Feasibility Analysis	
Suggested Content: A. What might customers be willing to pay for this product or service? B. How much might it cost the business to produce this product or service?	Evaluation Statements: A. The team's analysis is credible and the team has convincingly identified what the customer is willing to pay for the product. B. The team has thoroughly justified their product/service's cost of production and understands its implication on their profit margins.
4. Potential Impact	
Suggested Content: A. Who will benefit should this business succeed? B. What role will this business play in the energy transition?	Evaluation Statements: A. The proposed business includes thoughtful and specific activities that will advance equity and inclusion, including for members of disadvantaged communities[2] (e.g., those that are affected by persistent poverty, job loss due to the energy transition, etc.). B. The team has clearly outlined a realistic vision for the role, however large or small, they see this business playing in the energy transition.
5. Overall Business Plan	
Suggested Content: A. How is success defined? B. What people and resources are needed to put this plan into action?	Evaluation Statements: A. The team's definition of success is reasonable, and the business, if implemented as proposed, would be likely to achieve the specified metrics of success. B. The team has comprehensively identified what personnel, equipment or other assets, and partnerships are necessary to achieve success, as they have defined it.

HOW PITCH PHASE WINNERS ARE DETERMINED

The Prize Administrator screens all completed submissions and ensures compliance with all requirements in these rules and, in consultation with DOE, tasks reviewers to independently score the content of each submission. Expert reviewers will review submissions according to the evaluation criteria described in this document. DOE, at its sole discretion, may decide to hold short interviews with a subset of the competitors. These interviews will be held prior to the announcement of the winners. Interview attendance is not required, and interviews are not an indication of winning. The Pitch Phase final judge, a representative of OTT, will make

final selection of winners for both the National Prizes and the Technology Bonus Prizes based on the Pitch Phase reviewers scores and comments as well as the program policy factors described in these rules. Winners will be announced as part of the Pitch Phase event.

How We Score the Pitch Phase

A panel of expert reviewers will watch each team's pitch, and will read, score, and comment on each submission. Each bullet listed in the Pitch Phase evaluation statements receives a score from 1 to 6. The bullets have equal weight, so categories that have more review criteria bullets have a greater influence on the final score. The score from an individual reviewer for a submission package equals the sum of the scores for all the bullets. All reviewer's scores are then averaged for a final reviewer score for the submission package. The Pitch Phase final judge will consider reviewer scores when deciding the winners.

This prize seeks to encourage inclusivity and diversity, commercialization of national lab tech, and the pursuit of a broad mix of technologies. Before making the final selections/awards, reviewers will assess the portfolio against these dimensions. The final determination of winners will take reviewer scores, team presentation performance, reviewer deliberation, and program policy factors listed in the Additional Terms and Conditions into account.

Table 4: Scoring Scale

1	2	3	4	5	6
Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree

Pitch Phase Content and Evaluation Statements

For the Pitch Phase, teams present a comprehensive business plan that leverages a national lab-developed or other promising energy technology. Successful teams will demonstrate a clear understanding of the technology and its commercialization potential, the existing relevant market, and a will describe a convincing plan for commercialization. Teams will be given 10 minutes to present and 5 minutes for questions and answers from the reviewers. The judging panel will evaluate the teams using the evaluation statements in Table 5 and Table 7. Teams will be judged based on the extent to which the judging panel agrees with the evaluation statements. Winners are not determined based on the likelihood that the presenting team will implement the business plan, but rather the quality and innovativeness of the plan itself, should a qualified team of individuals attempt to

[2] Disadvantaged communities are those experiencing one or more of the following: Low income, high and/or persistent poverty, High unemployment and underemployment , Racial and ethnic residential segregation, particularly where the segregation stems from discrimination by government entities, Linguistic isolation, High housing cost burden and substandard housing, Distressed neighborhoods, High transportation cost burden and/or low transportation access, Disproportionate environmental stressor burden and high cumulative impacts, Limited water and sanitation access and affordability, Disproportionate impacts from climate change, High energy cost burden and low energy access, Jobs lost through the energy transition, Lack of access to healthcare.

execute the business plan.

Table 5: Pitch Phase Content and Evaluation Statements

Suggested Content:	Evaluation Statements:
1. Technology Identification	
A. What is the energy technology to be leveraged?	A. The team deeply understands their technology of choice and explained it clearly.
2. Market Assessment	
A. Who will buy the product or service, and why do they need the product or service? B. Who is currently serving this market? C. How can this technology help enable a business to better serve the market? D. How will the business find and secure customers?	A. The team deeply understands the range of potential customers for their identified technology, including what pain points this technology might solve for the customer. B. The team evaluated the entire relevant market of potential competitors. C. The team has clearly identified a strategy to serve a sizeable unmet market need. D. The team has developed a comprehensive strategy for finding and securing customers.
3. Economic Feasibility Analysis	
A. What are customers willing to pay for this product or service? B. How much will it cost the business to produce this product or service? C. How will the business become financially sustainable?	A. The team has thoroughly justified what the customer is willing to pay (e.g., via a detailed analysis of competitor offerings and what people pay for them today). B. The team deeply understands the steps necessary to produce and deploy the product/service and has thoroughly justified its cost of production. C. The team has a well-justified estimate of how much money they need to raise to get the project off the ground and has presented a realistic projection of when and how the company will attain positive cash flow and a sufficient return on investment.
4. Potential Impact	
A. Who will benefit should this business succeed? B. What role will this business play in the energy transition?	A. The proposed business includes thoughtful and specific provisions for advancing equity and inclusion, including for members of disadvantaged communities[3] (e.g., those that are affected by persistent poverty, job loss due to the energy transition, etc.). B. The team has clearly outlined a realistic vision for the role, however large or small, they see this business playing in the energy transition.
5. Overall Business Plan	
A. How is success defined? B. What people and resources are needed to put this plan into action?	A. The team's definition of success is reasonable, and the business, if implemented as proposed, would be likely to meet the specified metrics of success. B. The team has comprehensively identified what personnel, equipment or other assets, and partnerships are necessary to achieve success, as they have defined it.

HOW TECHNOLOGY BONUS PRIZE WINNERS ARE DETERMINED

The Prize Administrator screens all completed submissions and, in consultation with DOE, assigns expert reviewers to independently score the content of each submission. Expert reviewers will review submissions according to the evaluation criteria described in this document. A representative of OTT, will make final selection of winners for the Technology Bonus Prizes based on the Pitch Phase reviewers scores and comments as well as the program policy factors described in these rules. Winners will be announced as part of the Pitch Phase event. [3]

How We Score Technology Bonus Prizes

Subject matter experts selected by the Prize Administrator and OTT will individually evaluate the team pitches based on the pitch content and the written submission given in Table 7. Judges will meet after the Pitch Phase presentations to discuss and examine the teams with high average scores and will update their scores to reflect all the information available and determine winner(s).

Table 6: Scoring Scale

1	2	3	4	5	6
Strongly disagree	Disagree	Slightly disagree	Slightly agree	Agree	Strongly agree

Technology Bonus Prize Challenge and Evaluation Statements

For the Technology Bonus Prizes, teams present a comprehensive business plan that leverages a national lab-developed or other promising energy technology. The judging panel will evaluate the teams using the evaluation statements provided. Teams will be judged based on the extent to which the judging panel agrees with the evaluation statements.

[3] Disadvantaged communities are those experiencing one or more of the following: Low income, high and/or persistent poverty, High unemployment and underemployment , Racial and ethnic residential segregation, particularly where the segregation stems from discrimination by government entities, Linguistic isolation, High housing cost burden and substandard housing, Distressed neighborhoods, High transportation cost burden and/or low transportation access, Disproportionate environmental stressor burden and high cumulative impacts, Limited water and sanitation access and affordability, Disproportionate impacts from climate change, High energy cost burden and low energy access, Jobs lost through the energy transition, Lack of access to healthcare.

Table 7: Technology Bonus Prize Challenge and Evaluation Statements

Building Technologies Office (BTO)	
Challenge Statement: Develop innovative business models to increase the adoption of heat pumps for heating and cooling buildings in cold climate regions.	Evaluation Statements: The entry demonstrates a clear understanding of the technology and market potential for heat pumps and presents an innovative business model to significantly increase their adoption in cold climate regions.
Geothermal Technologies Office (GTO)	
Challenge Statement: Develop innovative business models to increase the adoption of geothermal technologies that address key exploration and operational challenges.	Evaluation Statements: The entry demonstrates a clear understanding of the technology and market potential for geothermal technologies and presents an innovative business model to significantly increase key exploration and operational challenges.
Office of Fossil Energy and Carbon Management (FECM)	
Challenge Statement: Develop innovative business models to increase the adoption of direct air capture (DAC), biomass carbon removal and storage (BiCRS), and/or mineralization technologies.	Evaluation Statements: The entry demonstrates a clear understanding of the technology and market potential for DAC, BiCRS, and/or mineralization technologies and presents an innovative business model to increase their adoption significantly and increase global market appeal.
Office of Nuclear Energy (NE)	
Challenge Statement: Develop innovative business models to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs.	Evaluation Statements: The entry demonstrates a clear understanding of the technology and market potential for nuclear energy and presents an innovative business model to significantly increase its adoption.
Solar Energy Technologies Office (SETO)	
Challenge Statement: Develop innovative business models to improve the affordability, reliability, and value of solar technologies on the U.S. grid and to tackle emerging challenges in the solar industry.	Evaluation Statements: The submission demonstrates a clear understanding of the technology and market potential for optimizing performance and/or reducing the costs associated with components, installation, and operation of solar energy systems and presents an innovative business model to significantly increase its adoption.
Water Power Technologies Office (WPTO)	
Challenge Statement: Develop innovative business models to improve or enhance the commercial potential of marine energy, particularly within blue economy markets, or next-generation hydropower and pumped storage systems.	Evaluation Statements: The submission demonstrates an understanding of the technology and market potential of the chosen technology, and the path to improving the technology and/or increasing its adoption is well-articulated and reasonable.

ADDITIONAL TERMS AND CONDITIONS

1. UNIVERSAL CONTEST REQUIREMENTS

Your submission for EnergyTech UP is subject to the following terms and conditions:

- You agree to release your stakeholder engagement tool under a Creative Commons Attribution 4.0 International License (see https://creativecommons.org/licenses/by/4.0/).
- You must include all the required submission elements. The Prize Administrator may disqualify your submission after an initial screening if you fail to provide all required submission elements. Competitors may be given an opportunity to rectify submission errors due to technical challenges.
- Your submission must be in English and in a format readable by Adobe Acrobat Reader. Scanned hand-written submissions will be disqualified.
- Submissions and competitors will be disqualified if any engagement with EnergyTech UP—including but not limited to the submission, the HeroX forum, or e-mails to the competition administrator—contains any matter that, at the sole discretion of DOE or the Prize Administrators, is indecent, obscene, defamatory, libelous, lacking in professionalism, or demonstrates a lack of respect for people or life on this planet.
- If you click "Accept" on the HeroX platform and proceed to register for the competition described in this document, these rules will form a valid and binding agreement between you and the U.S. Department of Energy. This agreement is in addition to the existing HeroX Terms of Use for all purposes relating to these contests. You should print and keep a copy of these rules. These provisions only apply to the contests described here and no other contests on the HeroX platform or anywhere else. To the extent that these rules conflict with the HeroX Terms of Use, these rules shall govern.
- The competition administrator, when feasible, may give competitors an opportunity to fix non-substantive mistakes or errors in their submission packages.
- Reviewers will review submissions according to the evaluation criteria described in this document. Expert reviewers may not (a) have personal or financial interests in, or be an employee, officer, director, or agent of any entity that is a registered competitor in the prize; or (b) have a familial or financial relationship with an individual who is a registered competitor. These judge requirements apply to all reviews across all regions.

2. PROGRAM POLICY FACTORS

While the scores of the expert reviewers will be carefully considered, it is the role of the Prize Administrator to maximize the impact of contest funds. Some factors outside the control of competitors and beyond the independent expert reviewer scope of review may need to be considered to accomplish this goal. The following is a list of such factors. In addition to the reviewers' scores, the below program policy factors may be considered in determining winners:

- Geographic diversity and potential economic impact of projects in a variety of solar markets
- Whether the use of additional DOE funds and provided resources continue to be nonduplicative and compatible with the stated goals of this program and DOE's mission generally

- The degree to which the submission exhibits technological or programmatic diversity when compared to the existing DOE project portfolio and other competitors
- The level of industry involvement and demonstrated ability to accelerate commercialization and overcome key market barriers
- The degree to which the submission is likely to lead to increased employment and manufacturing in the United States or provide other economic benefit to U.S. taxpayers
- The degree to which the submission will accelerate transformational technological, financial, or workforce advances in areas that industry by itself is not likely to undertake because of technical or financial uncertainty
- The degree to which the submission supports complementary DOE efforts or projects, which, when taken together, will best achieve the research goals and objectives
- The degree to which the submission expands DOE's funding to new competitors and recipients that have not been supported by DOE in the past
- The degree to which the submission exhibits team member diversity and the inclusion of underrepresented groups, including but not limited to graduates and students of historically black colleges and universities (HBCUs) and other minority serving institutions (MSIs) or members operating within Qualified Opportunity Zones or other underserved communities
- The degree to which the submission enables new and expanding market segments
- Whether the project promotes increased coordination with nongovernmental entities for the demonstration of technologies and research applications to facilitate technology transfer.

3. VERIFICATION FOR PAYMENTS

The Prize Administrator will verify the identity and the role of the participants potentially qualified to receive the prizes. Receiving a prize payment is contingent upon fulfilling all requirements contained herein. The Prize Administrator will notify winning competitors using their provided email contact information after the date that results are announced. Within 30 days of the date the notice is sent, each competitor (or parent/guardian if under 18 years of age) will be required to sign and return to the Prize Administrator a completed NREL Request for ACH Banking Information form and a completed W-9 form (https://www.irs.gov/pub/irs-pdf/fw9.pdf). At the sole discretion of the Prize Administrator, a winning competitor will be disqualified from the competition and receive no prize funds if: (i) the person/entity cannot be contacted; (ii) the person/entity fails to sign and return the required documentation within the required time period; (iii) the notification is returned as undeliverable; or (iv) the submission or person/entity is disqualified for any other reason.

4. TEAMS AND SINGLE-ENTITY AWARDS

The Prize Administrator will award a single dollar amount to the designated primary submitter, whether the submitter represents a single entity or multiple entities. The primary submitter is solely responsible for allocating any prize funds among its member competitors as they deem appropriate. The Prize Administrator will not arbitrate, intervene, advise on, or resolve any matters between team members or between teams.

5. SUBMISSION RIGHTS

By making a submission, and thereby consenting to the rules of the contest as described in this document, a competitor is granting to DOE, the Prize Administrator, and any other third parties supporting DOE in the

contest a license to display publicly and use all parts of any submission for any other Government purpose. This license includes posting or linking to any portion of the submission made via the competition administrator or HeroX applications, including the contest website, DOE websites, and partner websites, and the inclusion of the submission in any other media worldwide. The submission may be viewed by DOE, the competition administrator, and the reviewers for purposes of the contests, including but not limited to screening and evaluation purposes. The competition administrator and any third parties acting on their behalf will also indefinitely retain the right to publicize competitors' names and, as applicable, the names of competitors' team members and organizations that participated in the submission process on the contest website.

By entering, the competitor represents and warrants that:

1. The competitor's entire submission is an original work by the competitor, and the competitor has not included third-party content (such as writing, text, graphics, artwork, logos, photographs, dialogue from plays, likenesses of any third party, musical recordings, clips of videos, television programs, or motion pictures) in or in connection with the submission, unless (i) otherwise requested by the competition administrator and/or disclosed by the competitor in the submission, and (ii) the competitor has either obtained the rights to use such third-party content or the content of the submission is considered to be in the public domain without any limitations on use;
2. Unless otherwise disclosed in the submission, the use thereof by the competition administrator, or the exercise by the competition administrator of any of the rights granted by the competitor under these rules, does not and will not infringe or violate any rights of any third party or entity, including, without limitation, patent, copyright, trademark, trade secret, defamation, privacy, publicity, false light, misappropriation, intentional or negligent infliction of emotional distress, confidentiality, or any contractual or other rights;
3. All persons who were engaged by the competitor to work on the submission or who appear in the submission in any manner have:
    a. Given the competitor their express written consent to submit the submission for exhibition and other exploitation in any manner and in any and all media, whether now existing or hereafter discovered, throughout the world;
    b. Provided written permission to include their name, image, or pictures in or with the submission (or if a minor who is not the competitor's child, the competitor must have the permission of their parent or legal guardian), and the competitor may be asked by the competition administrator to provide permission in writing;
    c. Not been and are not currently under any union or guild agreement that results in any ongoing obligations resulting from the use, exhibition, or other exploitation of the submission.

6. COPYRIGHT

Each competitor represents and warrants that the competitor is the sole author and copyright owner of the submission; that the submission is an original work of the applicant or that the applicant has acquired sufficient rights to use and to authorize others, including DOE, to use the submission, as specified throughout the rules; that the submission does not infringe upon any copyright or upon any other third party rights of which the applicant is aware; and that the submission is free of malware.

Teams are not required to have secured a license or rights to a technology in order to present a business plan that leverages a specific technology, but they should have confidence that the technology could hypothetically be licensed or otherwise be made available to a team for use as part of their business model.

7. CONTEST SUBJECT TO APPLICABLE LAW

All contests are subject to all applicable federal laws and regulations. Participation constitutes each participant's full and unconditional agreement to these contest rules and administrative decisions, which are final and binding in all matters related to the contest. This notice is not an obligation of funds; the final awards are contingent upon the availability of appropriations.

8. RESOLUTION OF DISPUTES

The U.S. Department of Energy is solely responsible for administrative decisions, which are final and binding in all matters related to the contest.

Neither the U.S. Department of Energy nor the Prize Administrator will arbitrate, intervene, advise on, or resolve any matters between team members or among competitors.

9. PUBLICITY

The winners of these prizes (collectively, "winners") will be featured on the DOE and NREL websites.

Except where prohibited, participation in the contest constitutes each winner's consent to DOE's and its agents' use of each winner's name, likeness, photograph, voice, opinions, and/or hometown and state information for promotional purposes through any form of media worldwide, without further permission, payment, or consideration.

10. LIABILITY

Upon registration, all participants agree to assume, and thereby have assumed, any and all risks of injury or loss in connection with or in any way arising from participation in this contest and/or development of any submission. Upon registration, except in the case of willful misconduct, all participants agree to and thereby do waive and release any and all claims or causes of action against the Federal Government and its officers, employees and agents for any and all injury and damage of any nature whatsoever (whether existing or thereafter arising; whether direct, indirect, or consequential; and whether foreseeable or not) arising from their participation in the contest, whether the claim or cause of action arises under contract or tort.

11. RECORDS RETENTION AND THE FREEDOM OF INFORMATION ACT

All materials submitted to DOE as part of a submission become DOE records and are subject to the Freedom of Information Act. The following applies only to portions of the submission not designated as public information in the instructions for submission. If a submission includes trade secrets or information that is commercial or financial, or information that is confidential or privileged, it is furnished to the Government in confidence with the understanding that the information shall be used or disclosed only for evaluation of the application. Such information will be withheld from public disclosure to the extent permitted by law, including the Freedom of Information Act. Without assuming any liability for inadvertent disclosure, DOE will seek to limit disclosure of such information to its employees and to outside reviewers when necessary for review of the application or as

otherwise authorized by law. This restriction does not limit the Government's right to use the information if it is obtained from another source.

Submissions containing confidential, proprietary, or privileged information must be marked as described below. Failure to comply with these marking requirements may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. The U.S. Government is not liable for the disclosure or use of unmarked information, and may use or disclose such information for any purpose.

The submission must be marked as follows, and the specific pages containing trade secrets, confidential, proprietary, or privileged information must be identified:

Notice of Restriction on Disclosure and Use of Data:

Pages [list applicable pages] of this document may contain trade secrets or confidential, proprietary, or privileged information that is exempt from public disclosure. Such information shall be used or disclosed only for evaluation purposes. [End of Notice]

The header and footer of every page that contains confidential, proprietary, or privileged information must be marked as follows: "Contains Trade Secrets or Confidential, Proprietary, or Privileged Information Exempt from Public Disclosure." In addition, each line or paragraph containing proprietary, privileged, or trade secret information must be clearly marked with double brackets.

Competitors will be notified of any Freedom of Information Act requests for their submissions in accordance with 29 C.F.R. § 70.26. Competitors may then have the opportunity to review materials and work with a Freedom of Information Act representative prior to the release of materials.

12. PRIVACY

If you choose to provide HeroX with personal information by registering or completing the submission package through the contest website, you understand that such information will be transmitted to DOE and may be kept in a system of records. Such information will be used only to respond to you in matters regarding your submission and/or the contest, unless you choose to receive updates or notifications about other contests or programs from DOE on an opt-in basis. DOE and NREL are not collecting any information for commercial marketing.

13. GENERAL CONDITIONS

DOE reserves the right to cancel, suspend, and/or modify the contest, or any part of it, at any time. If any fraud, technical failures, or any other factor beyond DOE's reasonable control impairs the integrity or proper functioning of the contests, as determined by DOE at its sole discretion, DOE may cancel the contest.

Although DOE indicates that it will select up to several winners for each contest, DOE reserves the right to only select competitors that are likely to achieve the goals of the program. If, in DOE's determination, no competitors are likely to achieve the goals of the program, DOE will select no competitors to be winners and will award no prize money.

ALL DECISIONS BY DOE ARE FINAL AND BINDING IN ALL MATTERS RELATED TO THE CONTEST.

14. COMPETITION AUTHORITY AND ADMINISTRATION

EnergyTech UP is organized by DOE and NREL, which is managed and operated by the Alliance for Sustainable Energy, LLC, for DOE. Funding is provided by DOE OTT. The views expressed herein do not necessarily represent the views of DOE or the U.S. Government.

EnergyTech UP is governed and adjudicated by this rules document, which is intended to establish fair contest rules and requirements. The competition is designed and administered by a team consisting primarily of DOE and NREL staff. In the case of a discrepancy with other competition materials or communication, this document takes precedence. The latest release of these rules takes precedence over any prior release. The Prize Administrator reserves the right to change contest criteria, rules, and outcomes as needed. Additionally, competitors are encouraged to bring to the organizers' attention to rules that are unclear, misguided, or in need of improvement. For the purposes of competition evaluation, a violation of the intent of a rule will be considered a violation of the rule itself. Questions on these rules or the program overall can be directed to ott.energytechup@nrel.gov.

Expert reviewers may not (a) have personal or financial interests in, or be an employee, officer, coordinator, or agent of any entity that is a registered participant in the contest; or (b) have a familial or financial relationship with an individual who is a registered competitor in this contest.

By making a submission and consenting to the rules of this competition, each team member grants to the Government permission to use and make publicly available any entry provided or disclosed to DOE in connection with the competition. In addition, each team grants to the Government, and others acting on its behalf, a paid-up nonexclusive, irrevocable, worldwide license to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the U.S. Government, any and all copyrighted works that are or make up any submission.

EnergyTech UP and any associated nicknames and logos ("Competition Marks") are trademarks owned by DOE. The trademark license granted to contestants is below. Non-contestants can request individualized trademark licenses (for the purpose of engaging with contestants and/or expressing interest in the competition); the decision to grant such licenses is under the sole discretion of DOE.

1. Contestants are granted, for the duration of the competition, a revocable, nonexclusive, royalty-free license to use the Competition Marks for the purposes of producing materials for the competition and other approved competition-related activities, as long as the use does not suggest or imply endorsement of the contestant by DOE, and the use of the Competition Marks by a contestant does not imply the endorsement, recommendation, or favoring of the contestant by DOE.
2. Contestants may not use the Competition Marks for any other purpose. Contestants may not sublicense the Competition Marks.
3. All contestants can request individualized trademark licenses; the decision to grant such requests is under the sole discretion of DOE.

Further, from the Competes Act:

(j) Intellectual property

(1) Prohibition on the government acquiring intellectual property rights

The Federal Government may not gain an interest in intellectual property developed by a participant in a prize competition without the written consent of the participant.

(2) Licenses

As appropriate, and to further the goals of a prize competition, the Federal Government may negotiate a license for the use of intellectual property developed by a registered participant in a prize competition.

BUILDING TECHNOLOGIES OFFICE (BTO) BONUS FOCUS: COLD CLIMATE HEAT PUMPS

Statement of Interest

The Biden Administration set a goal to decarbonize the U.S. built environment by 2050. To meet this goal, we must address our existing, aging building stock, including heating and cooling systems.

Bonus Challenge

DOE's Building Technologies Office is challenging you to develop innovative business models to increase the adoption of heat pumps for heating and cooling buildings in cold climate regions.

Evaluation Statement

The presentation captures a clear understanding of the technology and market potential for heat pumps and presents an innovative business model to significantly increase their adoption.

Content

Introduction

President Biden has set a goal for the United States to achieve net-zero emissions by 2050.[4] Residential buildings will be part of that solution, accounting for approximately 21% of the country's total energy consumption.[5] About half of that energy is spent on heating and cooling,[6] and much of that is wasted due to older and inefficient technologies, among other factors.

Heat pumps are a technology for heating and cooling that is up to three times more energy efficient than other methods. This saves money on utility bills and reduces harmful greenhouse gas emissions. Heat pumps also utilize electricity to heat and cool, offering further potential environmental benefits. Switching from gas-powered heat to electricity can increase environmental benefits, as electricity can be generated from cleaner

[4] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/
[5] https://rpsc.energy.gov/energy-data-facts
[6] https://www.eia.gov/consumption/residential/data/2015/c&e/pdf/ce3.1.pdf

sources such as wind or solar technology. Finally, heat pumps can help control humidity, an important comfort factor in many regions of the United States.[7]

DOE's Building Technologies Office is challenging you to develop an innovative business model to increase the adoption of heat pumps for heating and cooling buildings in cold climates, where natural gas is most commonly used for heating.

Technology Overview

Heat pumps work by transferring heat energy from a cool space to a warm space using a refrigerant inside a coil, much like a refrigerator. In a heating system, the heat energy is transferred from a cooler space outside of a home to the warmer space inside, further warming it. In a cooling system, the opposite happens, working in the same way as a traditional air conditioning unit.[8]

Heat pumps can pull their heat energy from the air, ground, water, or another fuel source. Air-source heat pumps are the most common and most cost-effective. Air-source heat pumps use heat energy from the air inside and outside of the building. Geothermal heat pumps use heat from either the ground or a nearby water source. While more expensive, they are also more efficient overall, because ground and water temperatures remain more stable throughout the year than the air above. This is especially true in more extreme climates. Finally, absorption heat pumps are a newer technology that use a direct heat source such as gas.[9] This BTO bonus is offered for business models addressing any type of cold climate heat pump; however, air-source pumps are preferred.

Heat pumps are more efficient than other forms of heating because they simply move heat, rather than generating it. An air-source heat pump can deliver as much as three times as much energy in heat as the electrical energy required for the process.[10] By comparison, the most efficient gas-powered furnaces are 99% efficient, meaning that 99% of the energy (gas and electricity) used by the system is turned into heat.[11] It should be noted that heat pumps work most efficiently when there is a smaller temperature difference between the warmer and cooler spaces, meaning less heating and cooling is required. However, newer heat pump technology has been able to address every climactic condition in the United States.

Costs

There are two costs to consider when comparing heat pumps to other forms of heating for cold climate regions. The first is the upfront cost to install the technology, and the other is the cost to operate it. In a 2021 study by the Lawrence Berkeley National Laboratory, the median cost for all heat pump installations was reported at $8,027, although air-source heat pumps were about 75% of this cost. There were also added costs of less than 6% reported for cold climate installation. By comparison, the median cost for installing a gas furnace was $5,025.

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[7] https://www.energy.gov/energysaver/heat-pump-systems
[8] https://www.energystar.gov/products/ask-the-experts/how-does-a-heat-pump-work
[9] https://www.energy.gov/energysaver/heat-pump-systems
[10] https://www.energy.gov/energysaver/air-source-heat-pumps
[11] https://www.energy.gov/eere/femp/purchasing-energy-efficient-residential-furnaces

While the report did not specify costs for furnaces with integrated air conditioning, the median cost for installing central air conditioning systems was reported at $5,930.[12]

In terms of operational costs, heat pumps outperform other technologies due to their higher efficiency. For example, upgrading an old furnace to a new Energy Star certified gas-powered furnace can save homeowners nearly $140 per year.[13] But according to a study by the Northeast Energy Efficiency Partnerships, a properly installed heat pump can save anywhere from $300–$948 per year, depending on the type of heating system it is replacing and the local cost of gas and electricity.[14] Air-source heat pumps today are therefore cost-competitive with other heating and cooling systems on average, with the added benefit of combining both heating and cooling technologies in one unit.

Market Opportunity

The market opportunity for heat pumps may vary by region due to climate, technology, and the cost of natural gas and electricity in a particular area. Historically, heat pumps have mostly been used in hot and humid climates with mild winters, because this is where they tend to operate most efficiently. As an illustration, according to the most recent Residential Energy Consumption Survey, heat pumps were the main heating system for more than 15% of the homes in hot and mixed humid climates, but for only 3% of homes in cold and very cold climates.[15]

This is already starting to change as heat pumps grow in recognition. For example, U.S. manufacturer annual shipments of air-source heat pumps almost doubled between 2010 and 2020.[16] In Maine alone, more than 30,000 heat pumps have been installed since 2019, following a statewide goal to install 100,000 heat pumps by 2025.[17] With recent improvements in technology and efficiency, there is amazing opportunity for growth in adoption of this technology across the United States. However, the lingering association of heat pumps with warmer climates is the reason DOE is focused cold climate heat pumps for this prize bonus.

There are approximately 120 million households in the United States, and heat pumps are used in less than 20% of them. In addition, 29% of households reported that their home heating equipment was more than 15 years old, nearing the end of its lifecycle, and 22% of households with central air conditioning reported units at least 15 years old.[18] There are therefore tens of millions of potential new customers for heat pumps today, especially in colder regions. By 2050, potentially all heating and cooling units in use today will need to be replaced. There is almost no limit to the market potential for this technology, if it can shake off historical assumptions and connect with customers.

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[12] https://eta-publications.lbl.gov/sites/default/files/final_walker_-_the_cost_of_decarbonization_and_energy.pdf
[13] https://www.energystar.gov/campaign/heating_cooling
[14] https://www.energy.gov/energysaver/air-source-heat-pumps
[15] https://www.eia.gov/consumption/residential/data/2015/hc/php/hc6.6.php
[16] https://www.ahrinet.org/resources/statistics/historical-data/central-air-conditioners-and-air-source-heat-pumps
[17] https://www.naseo.org/news-article?NewsID=3664
[18] https://www.eia.gov/consumption/residential/data/2015/#ac

Additional Resources

- DOE – Heat Pump Systems
- Energy Star – How Does a Heat Pump Work
- Residential Energy Consumption Survey
- Northeast Energy Efficiency Partnerships - Market Strategies Report
- The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes

OFFICE OF FOSSIL ENERGY AND CARBON MANAGEMENT (FECM) BONUS FOCUS: CARBON DIOXIDE REMOVAL (CDR) AND CONVERSION

Statement of Interest

Deep decarbonization pathways that can be realistically applied in the United States were modeled to keep global temperatures outcomes within a 2°C, 1.5°C, and 1°C rise (Paris Agreement). The results showed that reaching net-zero emissions, including non-energy CO_2 from industrial processes, requires capturing carbon dioxide, which can be sequestered geologically or used to make carbon-neutral fuels feedstocks.[19] This was in addition to other mitigation strategies, e.g., energy efficiency, decarbonizing electricity, and switching from fuel combustion, in the end-uses, to electricity.[19] From reputable analysis, including the Intergovernmental Panel on Climate Change (IPCC), carbon dioxide removal will be required to meet the Paris targets.[20] Thus, carbon dioxide removal (CDR) technologies will play a vital role in carbon management. Therefore, the DOE's Office of Fossil Energy and Carbon Management (FECM) is challenging you to develop innovative business models to increase the adoption of CDR technologies, which may include direct air capture (DAC) coupled to durable storage, biomass carbon removal, and storage (BiCRS), marine CDR, and/or enhanced mineralization technologies.

Bonus Challenge

DOE's Fossil Energy and Carbon Management Office is challenging you to develop innovative business models to increase the adoption of CDR technologies.

Evaluation Statement

The presentation captures a clear understanding of the technology and market potential for CDR and presents an innovative business model that can increase the likelihood of CDR technology adoption.

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[19] https://doi.org/10.1029/2020AV000284
[20] Global CCS Institute, 2021. The Global Status of CCS: 2021. Australia.

Content

Introduction

President Biden has set a goal for the United States to achieve a 50% – 52% reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030.[21] This target builds on progress to date and positions American workers and industry to tackle the climate crisis.[21] The 2030 emission target, set by the National Climate Task Force and known as the "nationally determined contribution" or "NDC," supports President Biden's aim of reaching net-zero emissions economy-wide by no later than 2050.[21]

In contrast to most CO_2 abatement technologies that reduce emissions from point sources, CDR technologies remove CO_2 from the atmosphere and securely store it.[20] Paired with the simultaneous deployment of mitigation measures and other carbon management practices, CDR is a tool to address emissions from the hardest to decarbonize sectors, e.g., agriculture and transportation, and eventually, remove legacy CO_2 emissions from the atmosphere.[22] To meet the goal of achieving net-zero emissions by 2050, FECM funds research, development, demonstration, and deployment (RDD&D) of CDR technologies and conducts rigorous techno-economic and life cycle analyses, along with a deep commitment to environmental justice.

The proposed business model should be inclusive of all relevant unit flows for the applicable system. The business model can be multifaceted to be inclusive of any disaggregated product system. CDR processes must strive to maximize energy efficiencies and minimize costs.

Technology Overview

DAC technologies for CDR removal can be coupled with other techniques to store CO_2 from the atmosphere. DAC involves the direct removal of CO_2 from the atmosphere without photosynthesis.[20] Atmospheric CO_2 is very dilute and much harder to capture than industrial CO_2.[20] Comparatively large volumes of air must be handled for each tonne captured, and larger capture equipment is needed, so projects cost more than industrial CCS applications with the same capacity.[20] The thermodynamics of gas separation means the more dilute CO_2 also requires more energy to capture it.[20] Carbon capture and storage (CCS) provides the foundation for technology-based CDR through BiCRS and direct air carbon capture and storage (DACCS).[20] Interest in these two has surged in the last couple of years. [20]

BiCRS projects leverage photosynthesis to capture CO_2 and store it in biomass. This biomass is used for energy to create biofuels or via direct combustion, and the produced CO_2 is captured and stored in the subsurface.[20] BiCRS involves biomass conversion (power, fuels, etc.) coupled with carbon capture and storage.[20] Biomass conversion is generally considered carbon-neutral, as the amount of CO_2 released was taken out of the atmosphere during growth. Implementing carbon capture and storage with biomass conversion will lead to net-zero emissions, ultimately supporting the 2050 target goal.

[21] https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

The capture and storage of CO_2 can reduce carbon dioxide concentrations in the Earth's atmosphere.[22] One way to remove CO_2 from the atmosphere is via a geochemical method known as CO_2 mineralization, which occurs via carbonation reactions.[22] The carbon dioxide mineralization method is akin to the natural weathering process whereby rocks and minerals with high magnesium (Mg), calcium (Ca), or iron (Fe) content react with CO_2 to form a stable and inert carbonate rock.[22] In this process, the CO_2 is captured from the atmosphere during the reaction or supplied in a more concentrated form via injection into subsurface reservoirs or piping into surface industrial waste piles to increase the reaction rate significantly.[22] CO_2 mineralization reactions can utilize various materials in different settings and include the in-situ CO_2 mineralization of basalts or ultramafic rocks, the ex-situ mineralization of alkaline mine tailings, and reactions that produce other materials that have the potential to be used as mineral resources.[22]

Storing CO_2 through mineralization by injecting CO_2 fluids into subsurface rocks without first mining or crushing the rocks is in-situ CO_2 mineralization and is possible in basalts and ultramafic rocks.[22] Another method to store CO_2 through mineralization is by ex-situ reaction with crushed material at the surface.[22] Available crushed solid reactants include mine tailings derived from mafic or ultramafic rocks and alkaline industrial wastes. Often, these rocks are in the form of crushed mining waste, such as asbestos mine tailings, and carbon mineralization of asbestos mine tailings would have the added benefit of reducing the risks associated with exposed asbestos.[23] When using crushed material, the surface area of reaction is greater; therefore, the kinetics of the reaction are significantly faster, but the volume of resources available for carbonate mineralization is orders of magnitude less than that of in situ resources like basalts and ultramafic rocks.[22] However, the faster reactions and readily available material may prove to be more economical on small scales when attempting to create carbon-neutral electric powerplants or utilizing existing mine-waste material.[22] Thus, likely the best use for the ex situ reaction method would be close to industrial sites with carbon dioxide emissions, where the carbon could be captured before it goes into the atmosphere and immediately mineralized onsite.[23]

Mineral carbonation forms stable mineral carbonate products.[20] Stockpiles of alkaline waste provide a large sink for CO_2 and a potential source of generating side-stream products or opportunities to address expensive and hazardous wastes (for example, asbestos stabilization). The mineral carbonation process has been leveraged to produce building construction materials such as binders for cement and aggregates. CDR technologies that aim to pull carbon emissions out of the atmosphere and store legacy emissions in durable products like building materials are gaining attention and investments on a global scale.

Market Opportunity

Around half the anticipated emissions reductions to reach net-zero emissions by 2050 come from technologies not commercially deployed, and these new technologies become increasingly important after 2030.[24] CDR technologies, such as DAC and BiCRS, which help offset residual emissions, need to scale up significantly, too, giving rise to negative emissions.[24] A roadmap to net-zero emissions by 2050 showed for the G7 members (Canada, France, Germany, Italy, Japan, the United Kingdom, the United States) that carbon removal from BiCRS and DAC with storage offsets residual emissions of around 1.9 Gt, mainly in the transport and industry sectors, which is

[22] Carbon Dioxide Mineralization Feasibility in the United States. Scientific Investigations Report 2018–5079. U.S. Department of the Interior and U.S. Geological Survey. U.S. Geological Survey, Reston, Virginia: 2019.
[23] https://www.usgs.gov/news/making-minerals-how-growing-rocks-can-help-reduce-carbon-emissions.
[24] Achieving net-zero electricity sectors in G& members. International Energy Agency. October 2021.

currently the second-largest emitting sector.[24] Therefore, it is apparent that CDR technologies have an essential role in achieving net-zero emission targets by 2050 in the global market.

Many variables can impact the success of technologies, and these are likely to vary both temporally and regionally.[20] Generally, the market opportunity may be determined via a complete analysis of environmental and economic impact through life cycle analysis (LCA) and techno-economic analysis (TEA). An LCA is vital to deciding economic viability and environmental impact. An LCA is a tool used to quantify the net carbon reduction of a technology. Any successful projects must add economic value to their industry, which is why a TEA is essential.

Additional Resources

- Carbon Utilization Program | netl.doe.gov
- NETL CO2U LCA TRAINING RESOURCES | netl.doe.gov
- Conference Proceedings | netl.doe.gov

GEOTHERMAL TECHNOLOGIES OFFICE (GTO) BONUS FOCUS: INNOVATION AND INCLUSIVENESS

Statement of Interest

Geothermal energy, along with direct use of geothermal resources, presents an extraordinary opportunity to innovators and researchers seeking large-scale, deeply impactful outcomes as our nation aggressively builds toward a net-zero clean energy economy. At >90%, geothermal energy has the highest capacity factor among renewable energy sources, making it an invaluable component to electricity grid stabilization and load balance.

Bonus Challenge

GTO actively pursues novel thinking applied to innovative business (and technical) models that can increase the adoption of geothermal technologies by surmounting key exploration and operational challenges, namely those related to cost and risk reduction.

Evaluation Statement

The entry demonstrates a clear understanding of the technology and market potential for geothermal technologies. The entry also presents an innovative business model to significantly address key geothermal resource exploration challenges and/or enhance operational capabilities while engaging a diverse and inclusive cohort.

Content:

Introduction

Geothermal energy is heat derived from below the Earth's surface, which can be harnessed as a carbon-free, renewable energy around the clock with a small physical footprint. Geothermal is cosmic in origin – as opposed to atmospheric such as wind or water – and is constant, non-intermittent, and abundant in supply for as long as the Earth exists. It's an always-on source of secure, reliable, and flexible domestic energy that can be utilized across industrial, commercial, and residential sectors. The use of geothermal energy can also offer important

benefits to the nation, including grid stability, greater diversity in the portfolio of affordable energy options, and efficient heating and cooling.

As identified in the *GeoVision* analysis[25], the high costs and risks associated with geothermal exploration are a major barrier to expanded development of the nation's undiscovered, or "hidden," hydrothermal resources. Similarly, successful development of enhanced geothermal systems (EGS) resources—which require active engineering management throughout the life of the system—is dependent on resource characterization improvements, even once a project is in operation.

The *GeoVision* analysis illustrated that geothermal is America's untapped energy giant. Key findings about the potential for geothermal energy include:

- Improving technologies that reduce the costs and risks of geothermal development could increase geothermal power generation nearly 26-fold from today, representing 60 gigawatts-electric (GW_e) of electricity-generation capacity by 2050.
- The market potential for geothermal heat pump (GHP) technologies in the residential sector is equivalent to supplying heating and cooling solutions to 28 million households—14 times greater than existing installed capacity.
- The economic potential for district-heating systems is more than 17,500 installations nationwide, compared to the 21-total district-heating systems installed in the United States as of 2017.
- Improving permitting timelines alone could increase installed geothermal electricity-generation capacity to 13 GW_e by 2050—more than double the 6 GW_e projected in the Business-as-Usual scenario that serves as the baseline for the analysis.

Geothermal Technologies Overview

Geothermal Heating and Cooling

Geothermal heating and cooling utilize the hot water that already exists in hot springs and geothermal reservoirs near the surface of the earth, producing heat directly from hot water within the earth to heat and cool buildings, homes, and communities. Lower-temperature resources can also support other geothermal direct use applications in agriculture, recreation, and industry (e.g., food dehydration, gold mining, and milk pasteurizing).

Geothermal heating and cooling and other direct use systems typically have three components:

- A production facility—usually a well—to bring hot water to the surface
- A mechanical system—piping, heat exchanger, and controls—to deliver the heat to the space or process
- A disposal system—injection well, storage pond, or river—to receive the cooled geothermal fluid (does not apply to systems with "closed loops" where the fluid circulates continuously in the piping)

[25] www.energy.gov/geovision

Direct use geothermal systems, including geothermal heating and cooling, offer great opportunities to significantly expand the impact and reach of geothermal energy to a much wider swath of the country and could provide a large fraction of the energy demand currently supplied by high-grade fossil fuels. According to the *GeoVision* study, deployment of direct use could increase from 23 district heating systems today to as many as 17,500 systems by 2050. There is pronounced economic potential for geothermal district-heating systems in the Northeast corridor of the United States, and the Appalachian region is promising for direct use geothermal potential as well.

Geothermal district heating and cooling (GDHC) systems with a variety of different architectures can be designed to provide heating, cooling, and/or water heating to multiple buildings from a shared piping system. GDHC systems using geothermal heat pumps (see next section) are increasing in numbers in the United States. Newer GDHC systems circulate ambient-temperature water (roughly 50°–80°F) between buildings equipped with geothermal heat pumps. These systems can use a single pipe network to provide space heating, space cooling, and water heating to networks of buildings. Multiple studies and installations have shown that these types of systems can recycle heat between different buildings with different heating needs, thereby reducing capital cost, energy use, and resultant CO2 emissions. For example, a building with high occupancy and/or many computers may almost always be in a cooling mode. The extracted heat from that building warms the water in the shared pipe, and then another building that has a hot water need or space heating need can recover that heat instead of burning natural gas. These systems are commonly combined with geothermal boreholes to absorb heat or reject heat to the ground as needed.

Geothermal Heat Pumps (GHP)

Geothermal heat pumps are among the most efficient and comfortable heating and cooling technologies available because they use the Earth's natural heat to provide heating, cooling, and often, water heating. While many parts of the country experience seasonal temperature extremes—from scorching heat in the summer to sub-zero cold in the winter—a few feet below the earth's surface the ground remains a relatively constant temperature. The natural ground temperature is cooler than the natural air temperature in summer and warmer than the natural air temperature in winter.

The geothermal heat pump takes advantage of seasonal variation by transferring heat stored in the earth or in ground water into a building during the winter and transferring it out of the building and back into the ground during the summer. The ground, in other words, acts as a heat source in winter and a heat sink in summer. The benefit of ground source heat pumps is that they concentrate naturally existing heat, rather than produce heat through the combustion of fossil fuels.

Installing a geothermal heat pump system can be the most cost-effective and energy-efficient home heating and cooling option. Backyard geothermal heat pumps exist in homes in all U.S states and territories. Geothermal heat pumps are a particularly good option if you are building a new home or planning a major renovation to an existing home by replacing, for example, an HVAC system.

Geothermal heat pumps come in four types of systems that loop the heat to or from the ground and your house. Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth type of system is the open-loop option. Choosing the one that is best for your site depends on the climate, soil conditions, available land, and local installation costs at the site.

Closed-Loop Systems

- Horizontal: This type of installation is generally most cost-effective for residential installations, particularly for new construction where sufficient land is available. It requires trenches at least 4 feet deep.
- Vertical: This is often used for larger scale geothermal systems (such as in commercial buildings) where land is limited, or where the soil is too shallow to bury the horizontal loops in the trenches and some form of drilling into the bedrock is necessary. Vertical loop systems can be more expensive, but they use less land and minimize disturbance to the existing landscape.
- Pond/Lake: If the site has an adequate water body, this may be the least expensive option. A supply line pipe runs underground from the building to the water and coils into circles at least eight feet under the surface to prevent freezing. The coils should only be placed in a water source that meets minimum volume, depth, and quality criteria.

Open-Loop System

This type of system uses well or surface body water as the heat exchange fluid that circulates directly through the geothermal heat pump system. Once it has circulated through the system, the water returns to the ground through the well, a recharge well, or surface discharge. This option is practical only with an adequate supply of relatively clean water and when all local codes and regulations regarding groundwater discharge are met.

Residential Hot Water

In addition to space conditioning, geothermal heat pumps can be used to provide domestic hot water when the system is operating. Many residential systems are now equipped with desuperheaters that transfer excess heat from the geothermal heat pump's compressor to the house's hot water tank. A desuperheater provides no hot water during the spring and fall when the geothermal heat pump system is not operating; however, because the geothermal heat pump is so much more efficient than other means of water heating, manufacturers are beginning to offer "full demand" systems that use a separate heat exchanger to meet all of a household's hot water needs. These units cost-effectively provide hot water as quickly as any competing system.

According to the GeoVision study, 28 million geothermal heat pumps could be deployed nationwide by 2050. Geothermal heat pumps help decarbonize the grid by reducing peak and average loads while creating good paying jobs in every local community and enabling more solar and wind deployment.

Geothermal Electricity Production

The United States generates the most geothermal electricity in the world: more than 3.5 GW, predominantly from the western United States[26]. That's enough to power about 3.5 million homes. A geothermal resource requires fluid, heat, and permeability to generate electricity:

- Fluid—Sufficient fluid must exist naturally or be pumped into the reservoir.
- Heat—The earth's temperature naturally increases with depth and varies based on geographic location.

[26] 2021 U.S. Geothermal Power Production and District Heating Market Report (nrel.gov).

- Permeability—To access heat, the fluid must come in contact with the heated rock, either via natural fractures or through stimulating the rock.

Power plants use steam produced from geothermal reservoirs to generate electricity. There are three geothermal power plant technologies being used to convert hydrothermal fluids to electricity—dry steam, flash steam, and binary cycle. The type of conversion used (selected in development) depends on the state of the fluid (steam or water) and its temperature.

- Dry Steam Power Plant—Dry steam plants use hydrothermal fluids that are primarily steam. The steam travels directly to a turbine, which drives a generator that produces electricity. The steam eliminates the need to burn fossil fuels to run the turbine and also eliminates the need to transport and store fuels. These plants emit only excess steam and very minor amounts of gases. Dry steam power plants systems were the first type of geothermal power generation plants built (they were first used at Lardarello in Italy in 1904[27]). Steam technology is still effective today at currently in use at The Geysers in northern California, the world's largest single source of geothermal power.
- Flash Steam Power Plant—Flash steam plants are the most common type of geothermal power generation plants in operation today. Fluid at temperatures greater than 360°F (182°C) is pumped under high pressure into a tank at the surface held at a much lower pressure, causing some of the fluid to rapidly vaporize, or "flash." The vapor then drives a turbine, which drives a generator. If any liquid remains in the tank, it can be flashed again in a second tank to extract even more energy.
- Binary Cycle Power Plant—Binary cycle geothermal power generation plants differ from Dry Steam and Flash Steam systems in that the water or steam from the geothermal reservoir never comes in contact with the turbine/generator units. Low to moderately heated (below 400°F) geothermal fluid and a secondary (hence, "binary") fluid with a much lower boiling point that water pass through a heat exchanger. Heat from the geothermal fluid causes the secondary fluid to flash to vapor, which then drives the turbines and subsequently, the generators. Binary cycle power plants are closed-loop systems, and virtually nothing (except water vapor) is emitted to the atmosphere. Because resources below 300°F represent the most common geothermal resource, a significant proportion of geothermal electricity in the future could come from binary-cycle plants.

Additional Resources

- DOE – Geothermal Technologies Office
- Geothermal Energy 101
- The Drill Down: GTO's monthly newsletter captures the latest in geothermal news, including open funding opportunities, competitions and prizes, publications, events, and more.
- GEOVISION report**:** An analysis initiated by the U.S. Department of Energy's GTO to assess geothermal deployment potential. The report states that geothermal electricity generation capacity in the US has the potential to increase to more than 60 GW by 2050 (8.5% of all U.S. electricity generation).

[27] Larderello - the oldest geothermal power plant in the world (power-technology.com)

- 2021 U.S. Geothermal Power Production and District Heating Market Report: This report provides current information and data on 2019 geothermal power production and trends in U.S. district heating markets and technologies.
- U.S. Department of Energy Geothermal Data Repository (GDR): The GDR is the submission point for all data collected from researchers funded by the U.S. Department of Energy's (DOE) Geothermal Technologies Office (GTO). The GDR is powered by OpenEI, an energy information portal sponsored by the U.S. DOE and developed by the National Renewable Energy Laboratory in support of the Open Government Initiative to make energy data transparent, participatory, and collaborative.
- National Geothermal Data System (NGDS): The NGDS catalogs documents and datasets that provide information about geothermal resources located primarily within the United States. This complete and current catalog of available data, which is funded by the U.S. DOE GTO, is designed to accelerate the development of U.S. geothermal resources.
- Office of Scientific and Technical Information (OSTI): The U.S. DOE's OSTI database contains over 70 years of energy-related research results and citations collected by OSTI, consisting of nearly 3 million citations.
- Stanford/IGA Conference Database: This database contains papers and proceedings from a variety of geothermal-focused conferences, including the World Geothermal Congress, the Stanford Geothermal Workshop, and the New Zealand Geothermal Workshop, among others.
- Regulatory and Permitting Information Desktop (RAPID) Toolkit**:** A toolkit to help users access to permit documents, processes, best practices, manuals and related information in the geothermal industry.
- Geothermal Prospector**:** A tool that provides information about geothermal energy in the US, known geothermal resource areas and exploration regions, including state geothermal maps, potential for enhanced geothermal systems (EGS), low-temperature geothermal resources, and identified hydrothermal sites.
- Tribal Energy Atlas**:** A tool that explores techno-economic renewable energy potential on tribal lands, including wind, solar, geothermal, hydro, woody biomass, and biomethane.
- Geo-heat digital library**:** The library provides a large range of documents about geothermal energy. This collection is a partnership between the Oregon Institute Technology Libraries and the Geo-Heat Center of Oregon Renewable Energy Center.

OFFICE OF NUCLEAR ENERGY (NE) BONUS FOCUS: NUCLEAR ENERGY TECHNOLOGIES

Statement of Interest

DOE-Office of Nuclear Energy's (NE) mission is to advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs. NE has identified goals to address challenges in the nuclear energy sector, to help realize the potential of advanced technology, and to leverage the unique role of the government in spurring innovation:

1. Enable continued operation of existing U.S. nuclear reactors

2. Enable deployment of advanced nuclear reactors
3. Develop advanced nuclear fuel cycles and spent nuclear fuel management options.

Bonus Challenge

NE challenges you to develop innovative business models to improve or enhance the commercial potential of delivering innovative technologies for clean nuclear energy applications.

Evaluation Statement

The entry demonstrates an understanding of the technology and market potential of the chosen technology and the path to improved technology and/or enhanced adoption is well-articulated and reasonable.

Content

Introduction

NE conducts crosscutting nuclear energy research and development (R&D), and associated infrastructure support activities, to develop innovative technologies that offer the promise of dramatically improved performance for its mission needs as stated above, while maximizing the impact of DOE resources.

NE strives to promote integrated and collaborative research conducted by national laboratory, university, industry, and international partners in conjunction with NE's programs, and to deploy innovative nuclear energy technologies to the market in order to meet the strategic goals and optimize the benefits of nuclear energy.

NE funds research activities, through both competitive and direct mechanisms, as required to best meet those goals. This approach ensures a balanced R&D portfolio and encourages new nuclear power deployment with creative solutions to the universe of nuclear energy challenges.

Technology Overview

NE supports R&D in the following key NE program-related areas:

Fuel Cycle Research and Development (FC R&D) Program

The mission of the FC R&D program is to develop used nuclear fuel management strategies and technologies to support meeting the federal government responsibility to manage and dispose of the nation's commercial used nuclear fuel and high-level waste and to develop sustainable fuel cycle technologies and options that improve resource utilization and energy generation, reduce waste generation, enhance safety, and limit proliferation risk.

The program's vision is that by mid-century, strategies and technologies for the safe, long-term management and eventual disposal of U.S. commercial used nuclear fuel, and any associated fuel cycle technologies that enhance the accident tolerance of light water reactors and enable sustainable fuel cycles, are demonstrated and deployed. Together, these technologies and solutions support the enhanced availability, affordability, safety, and security of nuclear-generated electricity in the United States.

Reactor Concepts Research, Development, and Demonstration (RC RD&D) Program

The RC RD&D program conducts RD&D on existing and advanced reactor designs and technologies to enable

industry to address technical challenges with maintaining the existing fleet of nuclear reactors, and to promote the development of a robust pipeline of advanced reactor designs and technologies, and supply chain capabilities. Program activities are designed to address technical, cost, safety, and security issues associated with the existing commercial light water reactor fleet and advanced reactor technologies, such as small modular reactor (SMR) and microreactor designs, fast reactors using liquid metal coolants, and high-temperature reactors using gas or liquid salt coolants.

Nuclear Energy Enabling Technologies (NEET)

The NEET program conducts R&D in crosscutting technologies that directly support and enable the development of new and advanced reactor designs and fuel cycle technologies. These technologies will advance the state of nuclear technology, improve its competitiveness, and promote continued contribution to meeting our nation's energy and environmental challenges. The activities undertaken in this program complement those within the RC RD&D and FC R&D programs and support the DOE-NE mission. The knowledge generated through these activities will allow NE to address key challenges affecting nuclear reactor and fuel cycle deployment with a focus on crosscutting innovative technologies. Research areas include advanced modeling and simulation, advanced sensors and instrumentation, advanced materials and manufacturing technologies, nuclear cybersecurity, and integrated energy systems.

Market Opportunity

There is enormous potential to both expand into new markets and applications for nuclear energy, from the existing fleet on the nation's grid to advance reactors and fuel cycle technologies. Areas of opportunity include new technologies that can improve cost effectiveness and increase clean nuclear energy deployment.

There exist a number of market opportunities that broadly fall within the categories of (1) enable continued operation of existing U.S. nuclear reactors, which include activities designed to address technical, cost, safety, and security issues associated with the existing commercial light water reactor, (2) enable deployment of advanced nuclear reactors, and (3) Develop advanced nuclear fuel cycles and spent nuclear fuel management options.

Additional Resources

- DOE Office of Nuclear Energy
- History of Nuclear Energy
- Fuel Cycle Technologies
- Nuclear Energy Enabling Technologies
- Nuclear Facility Operations
- Nuclear Energy University Program
- Gateway for Accelerated Innovation in Nuclear (GAIN)
- Office of Nuclear Energy Funding Opportunities
- Nuclear Energy Institute
- Nuclear Innovation: Clean Energy Future
- Science-Technology-Engineering and Math (STEM) Resources

- Document Library
- Small Modular Reactor Technologies
- Light Water Reactor Technologies
- Advanced Reactor Technologies
- Versatile Test Reactor
- Space Power Systems

SOLAR ENERGY TECHNOLOGIES OFFICE (SETO) BONUS FOCUS: PERFORMANCE, AFFORDABILITY, RELIABILITY, AND VALUE OF SOLAR TECHNOLOGIES

Statement of Interest

Develop innovative business models to improve the performance, affordability, reliability, and value of solar technologies on the U.S. grid and to tackle emerging challenges in the solar industry.

Bonus Challenge

DOE's Solar Energy Technologies Office (SETO) is challenging you to develop an innovative business model for a selected novel solar technology of your choice that tackles emerging challenges in the solar industry and aims at improving the performance, affordability, reliability, and value of solar energy in the United States. The business model goal would be to increase the adoption of new solar technology and maximize the performance and/or reduce the costs associated with components, installation, and operation of solar energy systems.

Evaluation Statement

The entry demonstrates a clear understanding of the technology and market potential for optimizing performance and/or reducing the costs associated with components, installation, and operation of solar energy systems and presents an innovative business model to significantly increase its adoption.

Content

Introduction

President Biden has set goals for the United States to create a carbon pollution-free power sector by 2035 and to achieve net-zero emissions, economy-wide, by 2050.[28] Solar energy, being the fastest-growing electricity source,[29] is expected to be key part of the U.S. strategy to achieve such goals. Solar generation satisfied about 3% of the total U.S. electricity demand in 2020 and it is projected to serve 37-42% of electricity demand by

[28] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/
[29] https://www.c2es.org/content/renewable-energy/

2035.[30] Such substantial growth needs to be supported by technology innovation that addresses the emerging challenges in the solar industry and leads to advances in the performance, reliability, and affordability of solar systems.

Solar Technologies Overview

Solar radiation is light – also known as electromagnetic radiation – that is emitted by the sun. The amount of sunlight that strikes the earth's surface in an hour and a half is enough to handle the entire world's energy consumption for a full year. However, solar radiation is not a form of energy that can be used directly. Solar technologies capture this radiation and convert sunlight into useful forms of energy. For example, photovoltaic (PV) technologies convert sunlight into electricity that can be used directly or stored in batteries. Alternatively, mirrors can concentrate solar radiation to produce heat, which can generate electricity or be stored thermally.[31]

PV technologies – more commonly known as solar panels – generate power using devices that absorb energy from sunlight and convert it into electrical energy through semiconducting materials. These devices, known as solar cells, are then connected to form larger power-generating units known as modules or panels. The most common solar cells used in commercially available solar panels are made of crystalline silicon and have efficiencies typically ranging from 18% to 22%.[32] Photovoltaic installations exist as either large-scale electric utility plants or are more commonly found as residential, commercial, or industrial distributed energy resources (DERs) on building rooftops. Often, they are combined with energy storage (batteries), which are charged with solar energy and supply energy during nighttime or when sunlight is not available. Concentrating solar-thermal power (CSP) systems use mirrors to reflect and concentrate sunlight onto receivers that collect solar energy and convert it to heat in a high-temperature fluid, which can then be used to produce electricity, drive a variety of industrial applications, or be stored for later use. It is used primarily in very large power plants.[33]

Costs

Solar system costs comprise of the hardware costs of the various system components (e.g., solar panels, racking systems, solar inverters and other converters, electrical panels, electrical wiring and potentially battery storage) as well as a number of non-hardware costs, known as soft costs, such as permitting, financing, and installation costs. The levelized cost of energy (LCOE)[34] is a typical measure of the cost of energy production. LCOE is a measure of the average net present cost of electricity generation for a generating plant over its lifetime. It is used for investment planning and to compare different methods of electricity generation on a consistent basis.[35]

Over the past decade, solar energy has achieved significant cost reductions resulting in very competitive LCOE.[36] Though the cost may vary drastically based on the amount of sunlight and type of solar panels installed,

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[30] https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf
[31] https://www.energy.gov/eere/solar/how-does-solar-work
[32] https://www.energy.gov/eere/solar/crystalline-silicon-photovoltaics-research
[33] https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics
[34] https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf
[35] https://en.wikipedia.org/wiki/Levelized_cost_of_energy#:~:text=The%20levelized%20cost%20of%20energy,generation%20on%20a%20consistent%20basis.
[36] https://www.energy.gov/eere/solar/goals-solar-energy-technologies-office

currently the residential solar energy cost is about $0.08 to $0.10 per kWh on average while the commercial or utility-scale solar power cost is about $0.06 to $0.08 per kWh.[37] DOE is targeting a LCOE for solar of $0.02 to $0.05 per kWh by 2030.[38]

Focus Areas

This section lists several areas of interest where innovative technologies can advance the state of the art and, if they become commercially competitive, improve the performance, affordability, reliability, and value of solar systems. The list is not exhaustive, but it identifies several high-interest and high-potential areas.

Distributed Generation PV Systems

PV systems are typically found as rooftop installations operating as distributed energy resources. Residential rooftop PV installations are generally 3 to 10kW$_{DC}$ in size while commercial and industrial rooftop PV installations are more commonly > 30kW$_{DC}$ and ≤ 1MW$_{DC}$. Such systems can be grid-connected or isolated, stand-alone systems and are often coupled with energy storage systems (ESS) or also combined with electric vehicle (EV) charging systems. SETO is interested in technologies that can reduce installation costs of such PV, PV+ESS, or PV/ESS/EV systems (leading to increased DER penetration), optimize performance and control of such distributed generation systems, and allow such DER systems to provide support and services to the main grid, if needed.

Photovoltaic Cell Technologies and Materials

About 95% of solar panels on the market today use either monocrystalline silicon or polycrystalline silicon as the semiconductor.[39] But silicon cells have a maximum theoretical efficiency of about 32%, so researchers are exploring new materials and cell designs that can improve conversion and performance, such as[40]:

- Multijunction solar cells
- Thin-Film solar cells (CdTe)
- Perovskite solar cells
- Organic photovoltaics (OPV)

Building-Integrated Photovoltaics (BIPV) and Photovoltaic Building Materials (PVBM)

BIPV electric power systems 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.[41] BIPV and PVBM exist in various forms and types integrating solar panels on roofing products, building facades, curtain walls, fences, canopies, shade structures, or balcony balustrades.

Agrivoltaics

Dual-use solar refers to the concurrent use of land for both electricity and agricultural production. PV panels are installed on farmlands in a way that agricultural activities can continue, with agricultural production taking place underneath solar panels, in adjacent zones around the solar panels, or both. Agrivoltaic systems enable farmers,

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[37] https://homeguide.com/costs/solar-panel-cost
[38] Ibid. 9
[39] https://www.energy.gov/eere/solar/articles/pv-cells-101-primer-solar-photovoltaic-cell
[40] https://www.energy.gov/eere/solar/articles/pv-cells-101-part-2-solar-photovoltaic-cell-research-directions
[41] https://www.nrel.gov/docs/fy00osti/25272.pdf

ranchers, and other agricultural enterprises to gain value from solar technologies while keeping land available for agricultural purposes.[42] They can be used in both open-field agriculture, in the form of solar arrays above crops or arrays with spacing in-between them where crops can grow, as well as in controlled-climate agriculture, at greenhouses that use sunlight (not indoor farming with artificial light).

Floatovoltaics

A floating solar photovoltaic (FPV) system is 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.[43] 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 (e.g., oceans or lakes) or human-made water bodies, like freshwater reservoirs, wastewater ponds, or hydropower reservoirs.

Power Electronics

Power electronic (PE) devices are used to extract electric energy from the solar panels and make it available for use by other devices. Inverters are used to convert the direct current (DC) electricity generated by solar photovoltaic modules into alternating current (AC) electricity, which is used for local transmission of electricity, as well as most appliances in our homes, while DC/DC converters are used to convert the DC voltage of a PV module to a different DC voltage level. PV systems either have one inverter that converts the electricity generated by all the modules, or microinverters that are attached to each individual module. Advanced inverters, or "smart inverters," allow for a variety of functions that improves the performance of a solar system.[44, 45] Inverters and other PE converters typically use silicon-based power electronics. Recently new wide-bandgap semiconductor materials, like *silicon carbide* (SiC) have been used in PE devices demonstrating significant benefits and operating advantages, like smaller device sizes, less weight, and higher efficiencies.[46]

Additional Resources

- DOE – Solar Energy Technologies Office

Solar Technologies Background

- DOE/SETO – How Does Solar Work?
- DOE/SETO – Solar Energy Success Stories
- DOE/SETO – Solar Futures Study

Photovoltaic Technology Background

- DOE/SETO – Photovoltaics
- DOE/SETO – Solar Photovoltaic Technology Basics

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[42] https://www.energy.gov/eere/solar/seto-2020-solar-and-agriculture
[43] https://www.nrel.gov/state-local-tribal/blog/posts/floating-solar-photovoltaics-could-make-a-big-splash-in-the-usa.html
[44] https://www.energy.gov/eere/solar/solar-photovoltaic-system-design-basics
[45] https://www.energy.gov/eere/solar/solar-integration-inverters-and-grid-services-basics
[46] https://www.energy.gov/eere/solar/silicon-carbide-solar-energy

- NREL – Solar Photovoltaic Technology Basics
- EIA – Solar Explained
- SEIA – Photovoltaics
- SOLAREIS – Solar Photovoltaic Technologies

Next-Generation Power Electronics for Inverters/Converters

- DOE/SETO – Solar Power Electronic Devices
- DOE/SETO – Advanced Power Electronics Design for Solar Applications (Power Electronics)
- DOE/SETO – Silicon Carbide in Solar Energy

Perovskite Solar Cells

- DOE/SETO – Perovskite Solar Cells
- NREL – Perovskite Solar Cells

Building Integrated Photovoltaics (BIPV)

- SEIA – Building Integrated Photovoltaics
- NREL – Building Integrated Photovoltaic Designs
- WBDG – Building Integrated Photovoltaics (BIPV)

Agrivoltaics

- NCAT – AgriSolar Clearinghouse
- University of Arizona – What is Agrivoltaics?
- NREL – Benefits of Agrivoltaics Across the Food-Energy-Water Nexus

Floatovoltaics

- Sustainable Energy Coalition – Floatovoltaics: A solution for water and energy conservation?
- NREL – Floating Solar Photovoltaics Could Make a Big Splash in the USA
- NREL – Enabling floating solar photovoltaic (FPV) deployment

Appendix

Relevant LPS Technologies

1. Improved Method for Measuring Solar Irradiance (Sandia) – Inexpensive, efficient, and accurate method of measuring the irradiance from solar reflections using a digital camera.
2. Alternating Current Photovoltaic Building Block (Sandia) – Fully integrated and self-containing AC PV Building Block device and method that allows photovoltaic applications to become true plug-and-play devices.
3. Enhanced Thin Film Organic Photovoltaic Devices (BNL) – A novel structure design for thin film organic photovoltaic (OPV) devices provides a system for increasing the optical absorption in the active layer.
4. Molten Salt Heat Transfer Fluid (HTF) for Solar Thermal Power Plant Applications (Sandia) – HTF for use as thermal-energy storage medium at elevated temperatures that has a lower freezing point than any molten salt mixture available commercially.

Relevant Lab Partnering Service (LPS) Success Stories

Photovoltaic Cells and Panels

1. Sandia-led Center to Advance Understanding of New Solar Panel Technology (Sandia – 2021) – Research center to support perovskite technology performance, reliability, and bankability.
2. Sandia Scientists Provide Technical Assistance to Rocking Solar, an American-Made Solar Prize Finalist with a Product that could Transform the Urban Landscape (Sandia – 2021) – Single-axis tracking design for commercial rooftop solar.
3. Sandia-developed Solar Cell Technology Reaches Space (Sandia – 2021) – Solar cell technology of highly interconnected photovoltaic cells ('solar glitter') that reduces cost and increases efficiency.
4. Miniature Flexible Solar Panels (Sandia – 2020) – Microsystems-Enabled Photovoltaics (MEPV) technology ('solar glitter') with improved flexibility and ability to conform to shapes.
5. New Research Finds Power in Techno-economic Comparison of Bifacial and Tracking PV Systems Combinations (Sandia – 2020) – Techno-economic comparison of combinations of bifacial and tracking PV systems.
6. SunPower and Sandia Partnership Leads to Demonstration of Innovative New Module Technology (Sandia – 2020) – Experimental photovoltaic PV system at the New Mexico Regional Test Center (RTC), co-located with Sandia's Photovoltaic Systems Evaluation Laboratory (PSEL).
7. Crystal Solar and NREL Team Up to Cut Costs (NREL – 2014) – A faster and cheaper way to manufacture silicon solar cells by growing high-quality, high-efficiency silicon wafers at 100 times the usual throughput and half the cost.
8. Award-Winning Etching Process Cuts Solar Cell Costs (NREL – 2013) – Award-winning etching process allowing solar cells to absorb more than 98% of incident sunlight and reducing solar cell costs.

Concentrating Solar Power (CSP)

9. Sandia's Expertise Puts a Round 4 American-Made Solar Prize Winner's Innovation to the Test (Sandia – 2021) – Flat plate collector system, which integrates a novel aerogel insulating material within non-concentrating, flat plate collectors, enabling them to achieve high efficiencies with peak temperatures exceeding 150°C.
10. Testing Heat Exchangers Helps Move Solar Plans Forward (Sandia – 2021) – Evaluation of heat exchanger performance for concentrating solar power (CSP) projects.
11. STARS Harnessing the Sun to Make Gases and Chemicals (PNNL – 2019) – Technology that captures sunlight in a parabolic dish and concentrates it to drive a chemical reaction producing chemical energy with 70% efficiency.
12. Falling Particle Receiver for Concentrated Solar Energy (Sandia – 2018) – A falling-particle receiver for concentrating solar power systems (CSP) that moves sand-like ceramic particles, known as proppant, past the intensely concentrated sunlight beam to capture and store the heat more efficiently than the molten salts used in other CSP systems.

Solar Inverters and Power Electronics

13. NREL SolarCity and the Hawaiian Electric Companies (NREL – 2018) – Addressing the safety, reliability, and stability challenges of interconnecting high penetrations of distributed photovoltaics PV with the electric power system.

14. Hawaiian Electric Advances Solar Inverters (NREL – 2016) – Testing and performance demonstration of solar inverter functionality.
15. NREL + SOLECTRIA (NREL – 2015) – Development of 500- and 750-kilowatt photovoltaic (PV) inverters with advanced features that can support the electric grid.
16. NREL GOOGLE (NREL – 2015) – Little Box Challenge: an open competition challenging engineers to build smaller power inverters for use in photovoltaic (PV) power systems.

Hybrid PV+Storage Systems

17. Sandia App Assesses Value of Energy Storage for Businesses Utilities (Sandia – 2021) – Software ('Quest') to evaluate different energy storage scenarios and model the potential of new solutions.
18. Stafford Hill Microgrid (ORNL – 2018) – A 4MW/3.4MWh battery system coupled with over 2MW of solar photovoltaics PV located in western Vermont.
19. REopt Lite Tool to Optimize PV and Battery System Sizes (NREL – 2018) – Free online tool to help siting, sizing, and financially evaluating PV and battery storage projects.

Solar System Performance Evaluation

20. Sandia Uncovers Hidden Factors that Affect Solar Farms During Severe Weather (Sandia – 2021) – Advanced machine learning to study the impacts of severe weather on U.S. solar farms.
21. Rooftop Solar Panels Get Boost from Sandia Tool that Previews a Year on Grid in Minutes (Sandia – 2019) -- Simulation software that shows utility companies how rooftop solar panels at a specific house or business would interact with a local electrical grid throughout the year.
22. MOU Launches Collaboration to Study Photovoltaic Performance and Reliability Worldwide (Sandia – 2019) – Platform for studying photovoltaic performance and reliability in multiple diverse environments and climates.
23. SGHAT Software (Sandia – 2018) – Solar Glare Hazard Analysis Tool (SGHAT) is a web-based software platform, capable of evaluating the potential of glint/glare while optimizing energy production.

Safety/Security

24. Materials Developed at Sandia Help Extinguish Solar Panel Fires Before They Ignite (Sandia – 2020) – Development of electrical in-line connectors that automatically predict and prevent photovoltaic arc-faults before they can ignite electrical fires.
25. Ensuring Cybersecurity in Solar Energy Systems (Sandia – 2020) – Creation of cybersecurity standards and best practices for distributed energy resources.

WATER POWER TECHNOLOGIES OFFICE (WPTO) BONUS FOCUS

Statement of Interest

America has vast marine energy and hydropower resources and there remains enormous potential to both expand into new markets and applications and to increase generation and flexibility across the nation's sizable hydropower and pumped storage fleet.

Bonus Challenge

WPTO challenges you to develop innovative business models to improve or enhance the commercial potential of marine energy, particularly within blue economy markets, or next generation hydropower and pumped storage systems.

Evaluation Statement

The entry demonstrates an understanding of the technology and market potential of the chosen technology and the path to improved technology and/or enhanced adoption is well-articulated and reasonable.

Content

Introduction

America has vast marine energy and hydropower resources—and the continued development of new technologies and modernization and existing assets will be critical to furthering the nation's shorter-term electricity sector decarbonization goals, and to longer-term economy-wide focused objectives. Areas of opportunity include existing hydropower facilities and non-powered dams that can utilize new technologies to cost-effectively increase generation and flexibility; innovating on flexible and more rapidly deployable pumped energy storage systems; and advancing marine energy technology to support new and growing industries utilizing waves, currents, tides, and ocean thermal gradients.

Water power also has important benefits across multiple infrastructure sectors and to the people who depend on them. There are opportunities to evaluate how to harness and deliver water power, including through building more resilient infrastructure, providing power to produce clean water, unlocking the full potential of all ocean resources (Powering the Blue Economy or PBE), particularly in the context of climate change and its impact on our oceans, and better aligning technology development with end-users and communities. Therefore, WPTO is seeking new, innovative business models to improve or enhance the commercial potential of marine energy, particularly within blue economy markets, or next generation hydropower and pumped storage systems.

Technology Overview

Hydropower

Hydropower, or hydroelectric power, is one of the oldest and largest sources of renewable energy, which uses the natural flow of moving water to generate electricity. Hydropower currently accounts for 37% of total U.S. renewable electricity generation and about 7% of total U.S. electricity generation.[47] Hydropower technologies generate power by using the elevation difference, created by a dam or diversion structure, of water flowing in on one side and out, far below, on the other. Hydropower offers flexibility in both the short and long-term to support and complement variable renewable energy (VRE); pumped storage hydro (PSH) systems are one of the most scalable, cost-effective, and long-lived grid-scale storage assets, both now and likely in the future. Hydropower is a flexible, affordable energy source that compliments other renewable energy sources.

[47] https://www.eia.gov/energyexplained/hydropower/

Marine

Marine energy, also known as Marine Renewable Energy (MRE) or Marine and Hydrokinetic Energy (MHK), uses kinetic energy from moving water—including surface waves, tidal power, ocean current power, and other large bodies of moving water—to generate power and electricity. Marine energy technologies are at an early stage of development given fundamental technical challenges involved in generating power from a dynamic, low-velocity, and high-density resource while withstanding corrosive marine environments. However, given the significant resource potential in our oceans and rivers, marine energy offers both a future opportunity to supply electricity to a deeply decarbonized national grid and is a near-term solution for distributed energy for isolated and islanded communities.

Market Opportunity

There is enormous potential to both expand into new markets and applications for both marine and hydro and to extract more energy from the existing assets on the nation's grid. Areas of opportunity include existing hydropower facilities and non-powered dams that can utilize new technologies to cost-effectively increase generation and flexibility; innovating on flexible and more rapidly deployable pumped energy storage systems; and advancing marine energy technology to support new and growing industries utilizing waves, currents, tides, and ocean thermal gradients.

U.S. hydropower capacity continues to grow through upgrades to existing plants and other types of innovative new projects. Hydropower capacity has increased by a net of 431 MW since 2017, with total net growth of 1,688 MW from 2010 to 2019, mostly through capacity increases at existing facilities, new hydropower in conduits and canals, and by powering non-powered dams (NPDs).[48] At the end of 2019, an additional 1,490 MW, from 217 projects, were in the U.S. development pipeline, 93% of proposed capacity from powering NPDs and expanding existing facilities.[49] PSH represents a particular area of opportunity, as the vast majority of energy storage capacity in the U.S. is PSH, and PSH is the preferred least cost technology option for energy storage 4-16 hours in duration.[50] Hydropower and its facilities also present the opportunity to capitalize on several non-power benefits.[51]

As marine energy resources are sizable, predictable, reliable, can be developed in an environmentally responsible manner, and geographically diverse, marine energy represents a significant and emerging market across the entire U.S. and particularly in the "blue economy." The term "blue economy" refers to the sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystems. DOE's Powering the Blue Economy initiative seeks to understand the power requirements of coastal and maritime markets and advance technologies that integrate marine renewable energy to relieve these power constraints and enable sustainable growth of the blue economy.

In the blue economy, there exist a number of market opportunities that broadly fall within the categories of (1) power at sea, which involves providing power to support ocean-based industries, scientific observations and

[48] https://www.energy.gov/eere/water/downloads/us-hydropower-market-report
[49] Ibid
[50] https://www.eia.gov/energyexplained/hydropower/where-hydropower-is-generated.php.
[51] https://www.energy.gov/eere/articles/six-non-power-benefits-hydropower.

experiments, , and security activities (such as ocean observation and navigation or marine aquaculture) and (2) improving the resiliency of coastal communities by helping to meet their energy and water needs (for example, through desalination or powering microgrids in remote areas).[52]

Additional Resources

- DOE Water Power Technologies Office
- Water Power Technologies Office 2019-2020 Accomplishments Report
- Hydropower Explained
- HydroSource
- National Hydropower Association
- Hydropower Market Report
- Hydropower Geotechnical Foundations: Executive Summary
- Six Non-Power Benefits of Hydropower
- Portal and Repository for Information on Marine Renewable Energy (PRIMRE)
- Marine Energy Collegiate Competition Resources
- Marine Energy Resource Library
- Powering the Blue Economy

[52] https://www.energy.gov/sites/prod/files/2019/09/f66/73355-v2.pdf.