EnergyTech University Prize
2024 Official Rules Document

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Office of Technology Transitions

AMERICAN MADE
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Contents

Welcome to the EnergyTech University Prize

Welcome to the U.S. Department of Energy (DOE) Office of Technology Transitions (OTT) EnergyTech University Prize (EnergyTech UP)! In EnergyTech UP, student teams will compete for $450,000 in cash prizes for successfully identifying a promising energy technology, assessing its market potential, and creating a business plan for commercialization. Through the student portion of the competition, EnergyTech UP aims to cultivate the next generation of energy innovators while accelerating the transfer of energy technologies to market. In 2023 alone, the competition engaged more than 600 student participants within 184 teams from 124 collegiate institutions. By empowering a growing number of diverse students across the nation with knowledge and skills in the area of energy technology commercialization, DOE seeks to stimulate the growth of the next generation of clean energy technology entrepreneurs.

This prize seeks to attract and support 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, including university-developed technologies or other technologies of interest to student competitors.

A newly added Faculty Track of EnergyTech UP seeks to expand the impact of the student EnergyTech UP program. In the Faculty Track, individual faculty (or faculty teams) will compete for $100,000 in cash prizes for the successful development and implementation of educational activities (e.g., coursework, accelerator, program) that engage an increasing number of students on energy technology commercialization and entrepreneurship topics at their institution.

The goal of the EnergyTech UP Faculty Track is to increase the number and diversity of students who have access to educational activities that help them learn about energy technology commercialization and entrepreneurship. Participants in the EnergyTech UP Faculty Track will have access to and are expected to effectively leverage resource offerings from OTT, including but not limited to the EnergyTech UP student prize, Lab Partnering Service (LPS), Adoption Readiness Levels (ARL) framework, DOE's Pathways to Commercial Liftoff Reports, and asynchronous Energy I-Corps materials. These additional resources will help participants in the Faculty Track develop and provide transformational activities to effectively engage students in energy technology commercialization and entrepreneurship.

Participants in the Faculty Track will develop and produce an implementation plan that leverages DOE content, knowledge, and expertise to create activities that may help their own, and other, institutions increase the integration of energy technology commercialization and entrepreneurship into their activities. Faculty Track participants are also expected to demonstrate support for their project by relevant leadership (e.g., department chair, dean) at the home institution of the lead participating faculty member.

Importantly, this OTT program is seeking a diverse set of faculty, in background and institution type, that are passionate about the development and integration of educational activities centered on energy technology commercialization and entrepreneurship topics at their home institution. The content provided by faculty through their submissions are expected to inform a toolkit to be developed by OTT following the conclusion of this competition. The toolkit can potentially help other faculty across the nation build entrepreneurship and commercialization activities at their institutions.

This prize is sponsored by DOE's Office of Technology Transitions as well as several other DOE program offices. 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. Students interested in participating in the student prize will be provided with a curated list of national lab technologies that are ready for commercialization and that can be used in their business plan.

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 notify prize competitors of the revised document.

About the Office of Technology Transitions

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.

DOE's primary mission is to ensure our nation'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 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. In 2015, the Secretary of Energy authorized the formation of OTT, and in 2020, Congress formalized its establishment.

Summary of Important Dates

For the exact times and latest information, visit the HeroX competition platform.

- September 27, 2023: Rules published
- October 19, 2023: Informational webinar introducing EnergyTech UP
- November 15, 2023: Informational webinar focused on faculty Explore Phase submission deadline and bonus prizes
- December 5, 2023: Informational webinar focused on regional Explore Events
- January 5, 2024: Faculty submission deadline for Faculty Explorer prize consideration
- January 12, 2024: Office hours with Prize Administrators for interested students and faculty
- January 18, 2024: Office hours with Prize Administrators for interested students and faculty
- January 19, 2024: Faculty Explorer winners announced
- January 23, 2024: Recruiting webinar and team-building networking event
- February 1, 2024: Final student Explore Phase registration
- February 6, 2024: List of competing student teams announced
- February 13, 2024: Welcome and introductory webinar for all competing teams
- February 27, 2024: East regional events occur
- February 28, 2024: Central regional events occur

- February 29, 2024: West regional events occur
- March 7, 2024: Regional finalists and bonus prize finalists announced
- April 5, 2024: Business plans and recorded video due from all finalists and Implementation Phase submission package due from all faculty
- April 12, 2024: Final presentation files due from all finalists
- April 15, 2024: Final national competition event at Zpryme's Energy Thought Summit

Technology Areas of Interest

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

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 our nation's 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.

Student teams may focus their submissions on technologies developed at a national laboratory, technologies developed by the students themselves, technologies developed at their institution, or technologies developed by other entities. Teams are not required to have secured a license or rights to a technology to present a business plan that leverages that 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.

Several DOE technology offices are offering technology bonus prizes for the best student entries in each technology office's respective fields. Teams searching for a technology to build a business plan for are encouraged to engage with the Lab Partnering Service described below.

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. The formation of diverse student teams composed of individuals from groups historically underrepresented in science, technology, engineering, and mathematics (STEM) on their project teams is highly encouraged. Student teams are also highly encouraged to develop business plans that would benefit disadvantaged communities and/or underrepresented groups. Faculty teams are encouraged to submit work with high impact for teaching to underserved communities or underrepresented communities and/or teaching about how to ensure an equitable energy transition.

Further, to remove barriers to entry for all team members, the judging criteria have been established to determine success based on the strength of the proposal.

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 and consider additional opportunities.

Lab Partnering Service

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. 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. Any technology indicated on the LPS is eligible for consideration as part of the program.

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.

LPS also has a search tool called the Visual Patent Search (VPS). This tool enables a unique, visually facilitated search of the patent content in the LPS, which consists of published U.S. patent applications and issued U.S. patents resulting from research and development (R&D) funded by DOE as well as other organizations, namely NASA and the U.S. 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/

Energy I-Corps

Energy I-Corps, a key initiative of OTT, pairs teams of researchers with industry mentors for an intensive two-month training in which 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 their labs. In this way, Energy I-Corps is ensuring our investment in the national labs maintains and strengthens U.S. competitiveness over the long term.

All competing teams will receive access to recorded Energy I-Corps curriculum and associated materials. These materials are typically available only to national lab researchers.

Adoption Readiness Level and the CARAT Framework

To achieve deployment, a technology must be sufficiently de-risked, and ecosystem economics must be established so that every player in the value chain has a viable economic model. This means that managing a technology portfolio solely through the well-understood and widely used technology readiness levels (TRL) stage-gates is not enough. To describe adoption risks, OTT has developed the ARL framework to complement TRL, in partnership with other DOE and industry stakeholders. The framework assesses the adoption risks of a technology and translates this risk assessment into a readiness score, representing the readiness of a technology to be adopted by the ecosystem. Seventeen dimensions are used to determine a technology's ARL, and the Commercial Adoption Readiness Assessment Tool (CARAT) integrates these dimensions into an assessment.

Teams are encouraged to consider their technology's ARL and leverage CARAT to inform their entry.

DOE's Pathways to Commercial Liftoff Reports

DOE plays a critical role in accelerating the commercialization of clean energy technologies and enabling the nation's broader industrial strategy—creating high-quality jobs, strengthening domestic supply chains and global competitiveness, and facilitating an equitable energy transition. DOE's Pathways to Commercial Liftoff Reports provide public and private sector capital allocators with a perspective as to how and when various technologies could reach full-scale commercial adoption, including a common analytical fact base and critical signposts for investment decisions. The reports are living documents that will be updated periodically and can be found at Pathways to Commercial Liftoff.

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 300 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), which was authorized in Section 1001 of the Energy Policy Act of 2005. Student competitors are encouraged to review previous TCF awards for inspiration and to consider TCF funding as a possibility in any business plan developed. The TCF is an annual 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 aims to enhance DOE's technology transitions system with a forward-looking and competitive approach to lab-industry partnerships.

Technology Commercialization Internship Program

The annual OTT Technology Commercialization Internship Program (TCIP) 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. Student competitors of EnergyTech UP should consider applying to this internship program.

The TCIP includes the following:

- The program is an 11-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, students also undergo intensive training in commercialization through the Energy I-Corps curriculum.
- At the end of the program, students present their individual work in the form of business plan presentations, 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.

How to Enter

EnergyTech UP will utilize the HeroX website as its competition platform.

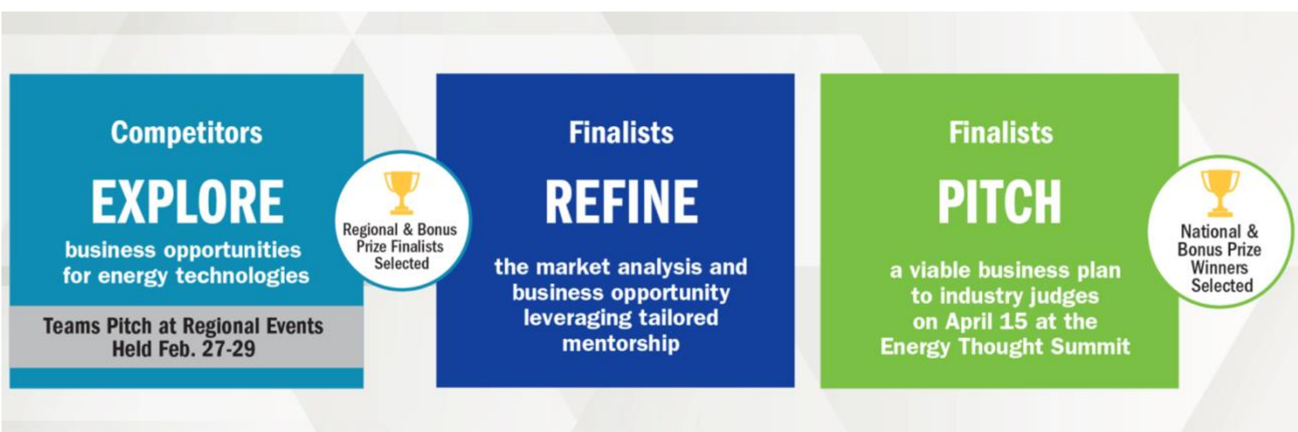
Go to https://www.herox.com/EnergyTechUP and follow the instructions for registering and submitting all required materials before the deadlines identified in the Summary of Important Dates section. Deadlines are also displayed on the HeroX website.

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 that 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 "Submit Final Entry" on HeroX to complete the team's registration. To do so, the team captain must first click "Begin Entry," fill out the required form fields, and then choose "Save & Preview." 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. Registration entries received by the deadline are deemed applicant teams.
6. Multiple student teams from a single school may compete and multiple faculty teams from a single school may compete.
7. Teams may have competitors from multiple schools.
8. 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.
9. Following the close of student Explore Phase registration, the Prize Administrators will review all registrations and may reallocate teams across regional conveners to ensure an appropriate and fair competition.
10. Email questions to the organizers at ott.energytechup@nrel.gov.

Student Track

The Student Track consists of three phases—the Explore Phase, the Refine Phase, and the Pitch Phase—as summarized in the following graphic:



Explore Phase

Student Teams will apply to become competitors by completing the registration entry form on the HeroX platform. Student applicants will submit a 200-word statement describing their proposed technology and associated business opportunity. Accepted teams will become competitor teams and will be given free access to OTT's Energy I-Corps curriculum to help them refine their ideas.

Student teams will then be invited to participate in a virtually held regional Explore event. A maximum of 15 competitor teams will present at each of up to 15 regional events. Each regional event will be held virtually by a regional convener located in the same geographic region as the team. Each team will have 8 minutes to explain their idea to a panel of judges (5 minutes for their initial pitch and 3 minutes for a Q&A period).

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 to present virtually live at the regional convener Explore Event. If a team has a faculty or industry advisor, the advisor is also encouraged to attend the Explore Event. Teams will be matched to a regional convener by the Prize Administrator after the submission deadline to ensure equitable distribution of teams across each regional Explore Event. Faculty, non-student team members, and industry advisors may not participate in the team presentation.

Regional Finalists: Up to one student team will be selected as a regional finalist from each of the up to 15 regional events. These teams will each be awarded $3,000 and invited to the Refine and Pitch phases. Up to $45,000 total will be awarded to regional finalists.

Technology Bonus Prize Finalists: From amongst all presenting teams, each program office offering a bonus prize may identify up to one Technology Bonus Prize finalist from each Technology Bonus Prize offered. These teams will be awarded $3,000 each and invited to the Refine and Pitch phases.

National Lab IP Licensing Bonus Prize Finalist: OTT may identify up to one National Lab IP Licensing Bonus Prize finalist from among the eligible presenting teams. This team will be awarded $3,000 and invited to the Refine and Pitch phases.

Undergraduate-Only Team Bonus Prize Semifinalists and Finalist: At the conclusion of each regional event, up to one student team will be selected as Undergraduate-Only Team Bonus Prize semifinalist. These teams' entries will then be reviewed by OTT who may identify up to one Undergraduate-Only Team Bonus Prize finalist. This team will be awarded $3,000 and invited to the Refine and Pitch phases.

Refine Phase

In the Refine Phase, all student finalist teams and faculty competitors will be provided with exclusive mentorship and continued free access to OTT's Energy I-Corps curriculum to help them refine their ideas.

All finalist teams will be paired with a mentor or mentors from industry, a national lab, or DOE. Mentors will give competitors insights into technology development and feedback on their plan in preparation for their Pitch Phase activities. Competitors are also encouraged to explore the Other Relevant Programs and Opportunities (described above) during this phase.

Pitch Phase

All finalist student teams will pitch their refined business plans at Zpryme's Energy Thought Summit in Austin, Texas, April 15–18, 2024. Student teams are expected to present in person at the event on April 15, 2024.

All student finalist teams will receive access to ETS's informative sessions designed to engage thought leadership on critically important topics for our nation's energy and innovation future. No registration or conference fee will be charged to any students or faculty associated with a finalist team to attend the ETS, though attendees are required to coordinate and pay for their own travel and lodging expenses.

National Prize Winners: The National First-Place Winner will be awarded $50,000, the National Second-Place Winner will be awarded $20,000, and the National Third-Place Winner will be awarded $10,000. A total of $80,000 in national prizes will be awarded.

Technology Bonus Prize Winners: The program offices sponsoring each of the Technology Bonus Prizes may identify and award prizes. Teams winning these prizes will each be awarded $22,000.

National Lab IP Licensing Bonus Prize Winner: One winner of the National Lab IP Licensing Bonus Prize may be identified and awarded by OTT. The winning team will be awarded $22,000.

Undergraduate-Only Team Bonus Prize Winner: One winner of the Undergraduate-Only Team Bonus Prize may be identified and awarded by OTT. The winning team will be awarded $22,000.

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

Student 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 postsecondary or higher education, including but not limited to community colleges, colleges, universities, and graduate schools.
    - Postsecondary students of any level are eligible to compete.
    - Students will self-certify their eligibility as part of registration for the competition.
    - Current collegiate level will be considered when determining eligibility for the Undergraduate-Only Team Bonus Prize.
    - 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. Students must be a majority of the team makeup.
- Expert reviewers, 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 for the national prizes, the team must be selected as a finalist.
- 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.
- This prize competition is expected to positively impact U.S. economic competitiveness. Participation in a foreign government talent recruitment program[2] could conflict with this objective by resulting in unauthorized transfer of scientific and technical information to foreign government entities. Therefore, individuals participating in foreign government talent recruitment programs of foreign countries of risk are not eligible to compete. Further, teams that include individuals participating in foreign government talent recruitment programs of foreign countries of risk[3] are not eligible to compete.
- Entities and individuals publicly banned from doing business with the U.S. government such as entities and individuals debarred, suspended, or otherwise excluded from or ineligible for participating in federal programs are not eligible to compete.

Prizes to Win

Explore Phase

Regional Finalists: At the conclusion of the Explore Phase, up to one team will be selected as a regional finalist from each of the up to 15 regional events. These teams will be awarded $3,000 and invited to the Refine and Pitch phases. Up to $45,000 total will be awarded to regional finalists.

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[2] A foreign government talent recruitment program is defined as an effort directly or indirectly organized, managed, or funded by a foreign government to recruit science and technology professionals or students (regardless of citizenship or national origin, and whether having a full-time or part-time position). Some foreign government-sponsored talent recruitment programs operate with the intent to import or otherwise acquire from abroad, sometimes through illicit means, proprietary technology or software, unpublished data and methods, and intellectual property to further the military modernization goals and/or economic goals of a foreign government. Many, but not all, programs aim to incentivize the targeted individual to physically relocate to the foreign state for the above purpose. Some programs allow for or encourage continued employment at U.S. research facilities or receipt of federal research funds while concurrently working at and/or receiving compensation from a foreign institution, and some direct participants not to disclose their participation to U.S. entities. Compensation could take many forms, including cash, research funding, complimentary foreign travel, honorific titles, career advancement opportunities, promised future compensation, or other types of remuneration or consideration, including in-kind compensation.

[3] Currently, the list of countries of risk includes Russia, Iran, North Korea, and China.

Technology Bonus Prize Finalists: From amongst all presenting teams, each program office offering a bonus prize may identify up to one Technology Bonus Prize finalist from the presenting teams for each Technology Bonus Prize offered. These teams will each be awarded $3,000 each and invited to the Refine and Pitch phases.

National Lab IP Licensing Bonus Prize Finalist: OTT may identify up to one National Lab IP Licensing Bonus Prize finalist from among the eligible presenting teams. This team will be awarded $3,000 and invited to the Refine and Pitch phases.

Undergraduate-Only Team Bonus Prize Semifinalists and Finalist: At the conclusion of each regional event, up to one student team will be selected as Undergraduate-Only Team Bonus Prize semifinalist from each of the regional events. These teams' entries will then be reviewed by OTT may identify up to one Undergraduate-Only Team Bonus Prize finalist. This team will be awarded $3,000 and invited to the Refine and Pitch phases.

Pitch Phase

At the conclusion of the Pitch Phase, DOE will award three national prizes, and several bonus prizes to student teams.

National Prizes: The National First-Place Winner will be awarded $50,000, the National Second-Place Winner will be awarded $20,000, and the National Third-Place Winner will be awarded $10,000. A total of $80,000 in national prizes will be awarded.

Technology Bonus Prizes: Each Technology Bonus Prize winner will each be awarded $22,000. The focus areas of each Technology Bonus Prize are provided in Table 6.

National Lab IP Licensing Bonus Prize: The National Lab IP Licensing Bonus Prize Winner will be awarded $22,000. The focus area of the National Lab IP Licensing Bonus Prize is provided in Table 6.

Undergraduate-Only Team Bonus Prize: One winner of the Undergraduate-Only Team Bonus Prize may be identified and awarded by OTT. The winning team will be awarded $22,000. The focus area of the Undergraduate-Only Team Bonus Prize is provided in Table 6.

A single team may win a national prize and one or more bonus prizes, a single prize in either category, or no prize at all.

What Students Submit

Registration

- A 200-word written summary addressing the energy technology to be leveraged and the business opportunity.
- A preliminary slide deck that summarizes the team's business plan, including the suggested content identified in Table 2 (Optional)
- A completed registration entry form on HeroX including answers to all required questions.

Explore Phase

- A 200-word written summary addressing the energy technology to be leveraged and the business opportunity.
- A slide deck that summarizes the team's business plan, including the suggested content identified in Table 4 and optionally in Table 6.
- A live (not recorded), virtual pitch to judges, 5 minutes in length, and participation in a 3-minute question-and-answer session with judges.
- A completed Explore Form entry form on HeroX including answers to all required questions.

Pitch Phase

- A written business plan that addresses the suggested content identified in Table 8, up to 10 pages in length.
- A recorded video explaining the technology to be leveraged and the business opportunity, up to 7 minutes in length.
- A slide deck that summarizes the team's business plan, including the suggested content identified in Table 8.
- A live pitch to judges, 6-minutes in length, in person at the ETS.

How Explore Phase Student Teams Are Determined

Eligibility Review

The Prize Administrator screens all completed registrations for eligibility. The Prize Administrator will review eligible submissions according to the evaluation criteria described in this document and will make the final selection of competing teams. Competing teams will then be assigned to a regional convener Explore Event as deemed appropriate by the Prize Administrator.

How We Score Team Registrations

The Prize Administrator will individually evaluate all eligible registration submissions and written statements given in Table 2 for their region using the scoring scale shown in Table 1.

Table 1: Scoring Scale

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

Registration Submission Evaluation Statements

As part of their registration, teams provide information about their team makeup and submit an initial 200-word summary that addresses the energy technology to be leveraged and the business opportunity. Teams may optionally submit a slide deck that summarizes their business plan, including some or all of the suggested content identified in Table 2. The Prize Administrator will evaluate the eligible teams using the evaluation statement provided in Table 2. Teams will be evaluated based on the extent to which the registration submission aligns with the evaluation statement.

Table 2: Registration Submission Evaluation Statement

Registration Submission Evaluation Statement	
Suggested Content: ● What is the energy technology to be leveraged? ● Who will buy the product or service, and why do they need the product or service? ● Who will benefit should this business succeed? ● What role will this business play in the energy transition?	**Evaluation Statement:** ● The team understands their technology of choice and has evaluated the relevant market, outlined a vision for the role the business could play in an equitable energy transition, and considered what would be necessary to achieve success.

Based on this review criteria, the Prize Administrator will select the teams who are invited to compete in each regional convener's Explore Event. These teams will then be asked to provide the submission materials described for the Explore Phase. During the Explore Phase, teams present their business plan to regional judges as part of a live event held virtually.

How Explore Phase Student Finalists Are Determined

Each regional convener will identify and secure a panel of judges to evaluate the Explore Phase presentations. Winners will be announced as part of each Explore 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 4 and Table 6 based on the presentation given by each team as part of a live event held virtually. Immediately following the conclusion of the Explore Phase presentations, judges will meet to determine which teams will be selected as regional finalists. Scores will not be shared with any of the teams. Only the regional finalists and semifinalists will be announced. Semifinalists are identified by combining eligibility criteria with the same evaluation criteria and process used for identifying regional finalists. Each bullet listed in the Explore Phase evaluation statements will receive 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 3.

Table 3: 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 one or more national lab-developed or other emerging energy technologies. The business idea should be developed independently by students. Teams will be given five minutes to present their technology and business plan, followed by three minutes of Q&A with the judges. 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 4 and in Table 6.

A panel of expert judges will evaluate, score, and comment on each submission. The evaluation statements have equal weight, the final score from an individual judge for a submission package equals the sum of the scores for all the statements. 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 finalist from their Explore Event. In addition to the finalist from each Explore Event, a semifinalist for the Undergraduate-Only Team Bonus Prize may be identified from each Explore Event.

This prize seeks to encourage inclusivity and diversity[4], commercialization of national lab technology, 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 by the Prize Administrator will consider reviewer scores, team presentation performance, reviewer deliberation, and program policy factors listed in Appendix A – Additional Terms and Conditions. Winners are not determined based on the likelihood that the presenting team will implement the business plan, but rather on the quality and innovativeness of the plan itself, should a qualified team of individuals attempt to execute the business plan.

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[4] Executive Order 14035 defines the term ''diversity'' as the practice of including the many communities, identities, races, ethnicities, backgrounds, abilities, cultures, and beliefs of the American people, including underserved communities.

Table 4: Explore Phase Content and Evaluation Statements

1. Technology Identification	
Suggested Content: • What is the energy technology to be leveraged?	**Evaluation Statement:** • The team deeply understands their technology of choice and explained it clearly.
2. Market Assessment	
Suggested Content: • Who will buy the product or service and why do they need it? • Who is currently serving this market and how? • What unmet market need will this technology help to fill?	**Evaluation Statement:** • The team understands the relevant market, potential competitors, and customers for their identified technology, including what pain points this technology might solve for the customer.
3. Economic Feasibility Analysis	
Suggested Content: • What might customers be willing to pay for this product or service? • How much might it cost the business to produce this product or service?	**Evaluation Statement:** • The team's analysis is credible and has identified what the customer is willing to pay for the product, thoroughly justifying their product/service's cost of production and understanding its implication on their profit margins.
4. Potential Impact	
Suggested Content: • Who will benefit should this business succeed? • What role will this business play in the energy transition?	**Evaluation Statement:** • The proposed business includes thoughtful and specific activities that advance, energy and environmental justice, equity and inclusion, including for members of disadvantaged communities[5]

[5] 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 (cont'd) (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

	(e.g., those that are affected by persistent poverty, job loss due to the energy transition, etc.), and the team has outlined a realistic vision for the role they see this business playing in the energy transition.
5. Overall Business Plan	
Suggested Content: • How is success defined? • What people and resources are needed to put this plan into action?	**Evaluation Statement:** • 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, including personnel, equipment or other assets, and partnerships necessary.

How Bonus Prize Finalists and Winners Are Determined

Finalists: The Prize Administrator screens all completed Explore Phase submissions and, in consultation with DOE, assigns eligibility for each bonus prize to each entry. The Prize Administrator will then assign expert reviewers to independently score the content of each submission, including a recording of the presentation provided by the team as part of an Explore Event. Expert reviewers will review submissions according to the evaluation criteria described in this document. A representative of OTT will make the final selection of finalists for the bonus prizes based on the expert reviewer's scores and comments as well as the program policy factors described in these rules.

Winners: The Prize Administrator will assign expert reviewers to independently score the content of each submission, including the pitch given by the team as part of the National Pitch Event. Expert reviewers will review submissions according to the evaluation criteria described in this document. A representative of OTT will make the final selection of winners for the bonus prizes based on the reviewers' scores and comments as well as the program policy factors described in these rules.

How We Score Bonus Prizes

Expert reviewers selected by the Prize Administrator and OTT will individually evaluate all team pitches based on the pitch content and the written submission given in Table 6. Judges will meet after the Pitch Phase presentations to discuss the teams with high average scores, update their scores to reflect all the information available, and determine winner(s).

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climate change, high energy cost burden and low energy access, jobs lost through the energy transition, and lack of access to healthcare.

Table 5: Scoring Scale

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

Bonus Prize Challenge and Evaluation Statements

For the 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 in Table 6. Teams will be judged based on the extent to which the judging panel agrees with the evaluation statements.

Teams are encouraged to review the content and references provided by each Program Office offering a Bonus Prize in Appendix B of these Rules. These summaries of the Program Office's area of interest and related industry landscape may provide valuable insights to teams as they identify potential technologies to leverage and the possible business opportunities.

Table 6: Bonus Prize Challenge and Evaluation Statements

Office of Technology Transitions (OTT) – National Lab IP Licensing Bonus Prize	
Challenge Statement: • Leverage the OTT's LPS to identify a national lab-developed technology available for license and propose an innovative business model to commercialize the technology.	**Evaluation Statement:** • The entry demonstrates a clear understanding of the technology and market potential of a technology listed on the OTT's Lab Partnering Service and presents an innovative business model to significantly increase its adoption.
Office of Technology Transitions (OTT) – Undergraduate-Only Team Bonus Prize	
Challenge Statement: • As a team made up of only undergraduate students, including those pursuing an associate's degree and those pursuing a bachelor's degree, demonstrate and propose an innovative business model for an emerging energy technology.	**Evaluation Statement:** • The eligible team presents an entry that demonstrates a clear understanding of the technology and market potential and presents an innovative business model to significantly increase its adoption.

Building Technologies Office (BTO) Technology Bonus Prize	
Challenge Statement: • Develop innovative business model(s) or commercialization plan(s) to increase the adoption of electrification solutions for commercial or residential HVAC technologies that increase market adoption and address industry challenges.	**Evaluation Statement:** • The entry demonstrates a clear understanding of the technology and market potential for electrification solutions for commercial or residential HVAC technologies and presents an innovative business model(s) or commercialization plan(s) to increase market adoption and address industry challenges. The entry can be multifaceted and propose solutions for both the commercial and residential sectors. The business model(s) or commercialization plan(s) must identify, outline and address challenges unique to each market sector.
Geothermal Technologies Office (GTO) Technology Bonus Prize	
Challenge Statement: • Develop innovative business models to increase the adoption of geothermal technologies that address key exploration and operational challenges.	**Evaluation Statement:** • The entry demonstrates a clear understanding of the technology and market potential for geothermal technologies and presents an innovative business model to significantly address key exploration and operational challenges while engaging a diverse and inclusive cohort.
Office of Fossil Energy and Carbon Management (FECM) Technology Bonus Prize	
Challenge Statement: • Develop innovative business models to increase the adoption of carbon dioxide removal (CDR) technologies.	**Evaluation Statement:** • The proposed business model should include all relevant unit flows for the applicable system and should clearly demonstrate that more CO_2 is removed from the atmosphere than emitted. The business model can be multifaceted to include any disaggregated product system. CDR processes must strive to maximize energy efficiencies and minimize costs.

<table>
<tr><th colspan="2">Office of Nuclear Energy (NE) Technology Bonus Prize</th></tr>
<tr><td>Challenge Statement:
Develop innovative business models to accelerate the development and deployment of advanced technologies supporting advanced reactors and fuel cycle technologies.</td><td>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.</td></tr>
<tr><th colspan="2">Office of Electricity (OE) – Grid-Enhancing Technologies (GETs) Technology Bonus Prize</th></tr>
<tr><td>Challenge Statement:
Develop innovative business models to increase the adaption of GETs to benefit the U.S. power grid.</td><td>Evaluation Statement:
The presentation emphasizes a clear understanding of GETs and the market potential for GETs to be implemented by various utility entities in a way that decreases congestion and reduces electricity costs.</td></tr>
<tr><th colspan="2">Office of Electricity (OE) - Large Power Transformers (LPTs) Technology Bonus Prize</th></tr>
<tr><td>Challenge Statement:
Develop innovative business models to stimulate the adoption of flexible LPTs in the electric sector.</td><td>Evaluation Statement:
The presentation emphasizes a clear understanding of the technology and market potential for flexible LPTs and presents an innovative business model to significantly increase their adoption.</td></tr>
<tr><th colspan="2">Office of Electricity (OE) - Long-Duration Energy Storage (LDES) Technology Bonus Prize</th></tr>
<tr><td>Challenge Statement:
Develop innovative business models to propose an LDES technology solution, explain the technology’s use case, and address market challenges to enable greater adoption of LDES on the U.S. power system. Innovative energy storage use cases are encouraged.</td><td>Evaluation Statement:
The presentation outlines a clear understanding of LDES technologies and the LDES market space, explores barriers to greater LDES adoption, and proposes an innovative business plan to accelerate LDES deployment for a defined, innovative use case.</td></tr>
</table>

Solar Energy Technologies Office (SETO) Technology Bonus Prize	
Challenge Statement: ● 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.	**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.
Hydrogen Fuel Technologies Office (HFTO) Technology Bonus Prize	
Challenge Statement: ● Develop innovative business models to identify mechanisms for commercially viable hydrogen technologies to achieve market liftoff, supporting domestic competitiveness, job creation, and achievement of climate goals.	**Evaluation Statement:** ● The entry demonstrates a clear understanding of the technology and market potential for hydrogen technologies and presents an innovative business model to significantly increase its adoption.
Office of Manufacturing & Energy Supply Chains (MESC) Technology Bonus Prize	
Challenge Statement: ● Develop innovative and practical business models for deployment of smart manufacturing solutions at small and medium-sized manufacturers -- recognizing the need for retrofit projects that accommodate the inherent implementation challenges of these solutions with uncertain payback periods and financing obstacles.	**Evaluation Statement:** ● The entry emphasizes a clear understanding of, and plans to address, both the immense opportunities and challenges associated with SMART manufacturing specifically at small and medium-sized manufacturers..
Water Power Technologies Office (WPTO) Technology Bonus Prize	
Challenge Statement: ● Develop innovative business models for a selected novel hydropower or marine technology of your choice that tackles emerging challenges in the water power industry and aims at	**Evaluation Statement:** ● The entry 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

improving the performance, affordability, reliability, and value of hydropower or marine energy in the United States.	and reasonable. The team demonstrates a commitment to diversity, equity, inclusion, and justice.

How Pitch Phase Student 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 with independently scoring 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 based on the Pitch Phase judges' scores and comments as well as the program policy factors described in these rules. Winners will be announced as part of the Pitch 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, as indicated in Table 7. The bullets have equal weight, so categories that have more review criteria 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 reviewers' 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 laboratory technology, 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 consider reviewer scores, team presentation performance, reviewer deliberation, and program policy factors listed in Appendix A – Additional Terms and Conditions.

Table 7: 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 submit a comprehensive business plan that leverages a national lab-developed or other promising energy technology and a prerecorded pitch. Successful teams will demonstrate a clear understanding of the technology and its commercialization potential, the existing relevant market, and a convincing plan for commercialization. Pitch Phase judges will review the business plan and prerecorded pitch and provide up to three statements of concern or questions to each team at least 48 hours prior to the deadline to submit the presentation file. Teams can then choose to address those statements in their live pitch. Teams will be given up to 6 minutes to present. The judging panel will evaluate the teams using the evaluation statements in Table 8. 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 on the quality and innovativeness of the plan itself, should a qualified team of individuals attempt to execute the business plan.

Table 8: Pitch Phase Content and Evaluation Statements

<table>
<tr><th colspan="2">1. Technology Identification</th></tr>
<tr><td>Suggested Content:
What is the emerging energy technology to be leveraged in the proposed business?</td><td>Evaluation Statement:
The team deeply understands their technology of choice and explained it clearly.</td></tr>
<tr><th colspan="2">2. Market Assessment</th></tr>
<tr><td>Suggested Content:
Who will buy the product or service, and why do they need the product or service?
Who is currently serving this market?
How can this technology help enable a business to better serve the market?
How will the business find and secure customers?</td><td>Evaluation Statement:
The team deeply understands the range of potential customers for their identified technology, including what pain points this technology might solve for the customer.
The team has evaluated the entire relevant market of potential competitors.
The team has clearly identified a strategy to serve a sizable unmet market need.
The team has developed a comprehensive strategy for finding and securing customers.</td></tr>
<tr><th colspan="2">3. Economic Feasibility Analysis</th></tr>
<tr><td>Suggested Content:
What are customers willing to pay for this product or service?
How much will it cost the business to produce this product or service?</td><td>Evaluation Statement:
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).</td></tr>
</table>

• How will the business become financially sustainable?	• The team deeply understands the steps necessary to produce and deploy the product/service and has thoroughly justified its cost of production. • 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	
Suggested Content: • Who will benefit should this business succeed? • What role will this business play in the energy transition?	**Evaluation Statement:** • The proposed business includes thoughtful and specific provisions for advancing equity and inclusion, including for members of disadvantaged communities (See footnote 2 on page 16) (e.g., those that are affected by persistent poverty, job loss due to the energy transition, etc.). • 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: • How is success defined? • What people and resources are needed to put this plan into action?	**Evaluation Statement:** • 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. • The team has comprehensively identified what personnel, equipment or other assets, and partnerships are necessary to achieve success, as they have defined it.

Faculty Track

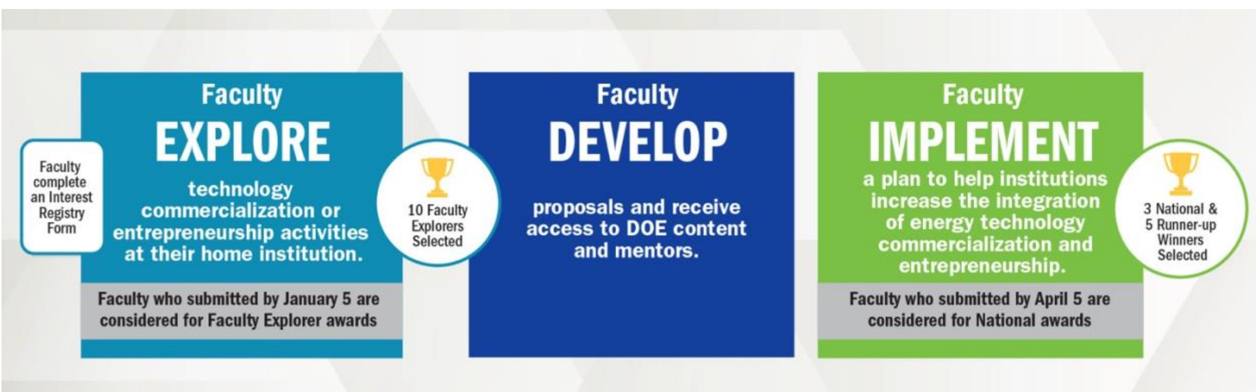
The Faculty Track seeks applications from faculty interested in incorporating or expanding energy technology commercialization and entrepreneurship topics into their institution's educational activities. The Faculty Track consists of three phases—the Explore Phase, the Develop Phase, and the Implementation Phase.

DOE recognizes that some faculty may already have significant experience and therefore sufficient support to successfully implement their plan for the 2024/2025 academic year while others may require more time to develop and implement their educational activities—both approaches are welcome. DOE seeks thoughtful educational activities with a high likelihood of effective and impactful implementation that expands technology commercialization and entrepreneurship education across a diverse[6] student population.

Examples of incorporation and expansion of proposed educational activities include (but are not limited to):

- The integration of new key educational modules into an existing course(s)/program.
- The development of a new course(s)/program.
- The creation of an accelerator or incubator program.
- Creative co-teaching situations involving faculty from different disciplines.
- Creative distance learning modules/course(s).
- The creation of new student-centered materials that actively engage learners in the classroom.
- The development of new content presentation materials (for in-person or online learning), or any other approach determined to be impactful by the faculty and supported by their department/administration.

The content provided by faculty through their submissions are expected to inform a toolkit to be developed by OTT following the conclusion of this competition, The toolkit can potentially help other faculty across the nation build entrepreneurship and commercialization activities at their institutions.



[6] Executive Order 14035 defines the term ''diversity'' as the practice of including the many communities, identities, races, ethnicities, backgrounds, abilities, cultures, and beliefs of the American people, including underserved communities.

Interest Registry

Through the Interest Registry, faculty who plan to apply to be a competitor for the Implementation Phase will submit their information to the Interest Registry Form (accessible from the HeroX platform). Submissions will be on a rolling basis and will consist of the faculty's name, email, and name of their institution. This will allow DOE to communicate with faculty during the Develop and Implementation phases and provide resources to interested faculty. As an example, a webinar will be hosted to share DOE resources that are available; those who have completed the Interest Registry will be invited to such events.

Explore Phase

Faculty who submit an Explore Phase entry on HeroX and meet eligibility requirements become faculty competitors and will be given free access to several resources to help them refine their ideas and learning materials.

The Explore Phase is intended to support participants who are excited to implement entrepreneurship and/or commercialization activities but may not have deep integration of energy technology commercialization or entrepreneurship activities in their home institution. As such, these participants may need the resources provided by the Explore Phase to create an implementation plan.

Faculty (or faculty teams) apply to the Explore Phase by completing the registration entry form on the HeroX platform. The focus of the Explore Phase is identifying faculty with promising interest, ideas, and/or materials who are likely to effectively develop, refine and implement high-quality and impactful activities for a student population that does not currently have access to these kinds of opportunities.

Participants must also demonstrate that they have preliminary interest/support for their proposal from institutional leadership (e.g., a department chair, associate dean, or dean). For the Explore Phase, competitors do not need to have any current integration of energy technology commercialization or entrepreneurship in their institution's activities.

Faculty Explorers: Up to 10 faculty (or faculty teams) will be identified as Faculty Explorers from among the Explore Phase submissions received by January 5, 2024. Faculty Explorers will each be awarded $4,000 and encouraged to participate in the Develop and Implementation phases. A letter will also be sent to their institution on behalf of DOE announcing the prize award. Up to $40,000 in total will be awarded to Faculty Explorers. All faculty competitors, including Faculty Explorers, are eligible to compete in the Implementation Phase.

Develop Phase

In the Develop Phase, all faculty who submitted their information to the Interest Registry and all faculty competitors identified as part of the Explore Phase, including those identified as Faculty Explorers, will be provided with mentorship and continued free access to DOE resources.

All faculty competitors will be given access to a mentor from DOE. Mentors will give competitors insights and feedback on their plan in preparation for their implementation plan submission.

Faculty competitors are encouraged to explore all DOE OTT resources, including the Adoption Readiness Levels Framework, the Lab Partnering Service, Pathways to Commercial Liftoff Reports, and other materials. By the end of the Develop Phase, all competitors are highly encouraged to incorporate in their proposals the ARL concepts and framework in a logical and intentional manner for the educational benefit of students engaged with the activities. However, proposals can be submitted with alternative frameworks or approaches.

Implementation Phase

Any eligible faculty may submit an implementation plan on or before April 5, 2024. Selected winners will be announced as part of Zpryme's Energy Thought Summit in Austin, Texas, April 15–18, 2024. Faculty are not expected to present in person at the EnergyTech UP portion of the event on April 15, 2024, but may attend if interested.

Proposals should include how this topic could be integrated into student activities along with a letter of support signed by the relevant department chair or administrator such as an associate dean, dean, provost, or vice provost.

The implementation plan submitted as part of this phase should include a timeline for implementation at the competitor's home institution. Competitors should indicate if implementation is possible in the 2024/2025 academic year.

Faculty Winner: Up to eight faculty competitor teams will be identified as winners. The first-place winner will be awarded $25,000, the second-place winner will be awarded $15,000, and the third-place winner will be awarded $10,000. Five additional entries will be awarded $2,000 each and identified as runner-up winners. While Explore Phase Faculty Explorers will be encouraged to advance to the Develop and Implementation phases, any eligible faculty who submits a complete package by the Implementation Phase deadline is eligible to be identified as a faculty winner.

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

Faculty Eligibility

- All participating faculty must be employed by an accredited collegiate institution.
    - For the purposes of this competition, "collegiate institution" refers to a school of postsecondary or higher education, including but not limited to community colleges, colleges, universities, and graduate schools.
    - Faculty will self-certify their eligibility as part of the registration for the competition.
    - Faculty may compete as a single-individual team or as a member of a team with multiple faculty members.
    - Teams with faculty from multiple collegiate institutions are allowed, and multiple faculty teams from the same collegiate institution are allowed.
    - Faculty may be full-time or part-time employees of their institution.
- All faculty teams must identify a single team captain/lead.
- All faculty competing as individuals, and all faculty team captains must be U.S. citizens or permanent residents.

- The final submission must come from the faculty competing as an individual or in the case of a team, by the team captain's HeroX account.
- A team may have non-faculty team members or advisors who provide input and guidance and support the development of the idea.
- Expert reviewers, 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.
- The faculty (or faculty team) does not need to have been selected as a Faculty Explorer to be eligible to compete for the Implementation Phase faculty prizes.
- By uploading a submission package, the faculty (or faculty team) self-certifies that it is compliant with the eligibility requirements. If the Prize Administrator becomes aware that a team or individual is not eligible, that team may be disqualified from competition.
- This prize competition is expected to positively impact U.S. economic competitiveness. Participation in a foreign government talent recruitment program[7] could conflict with this objective by resulting in unauthorized transfer of scientific and technical information to foreign government entities. Therefore, individuals participating in foreign government talent recruitment programs of foreign countries of risk are not eligible to compete. Further, teams that include individuals participating in foreign government talent recruitment programs of foreign countries of risk[8] are not eligible to compete.

Prizes to Win

Explore Phase

Faculty Explorer Prize: From among eligible entries submitted by the deadline, up to 10 faculty or faculty teams will be selected as Faculty Explorers. These teams will be awarded $4,000 each and encouraged to continue to the Develop and Implementation phases. A maximum of $40,000 total will be awarded to Faculty Explorers. A letter will also be sent to their institution on behalf of DOE announcing the prize award.

[7] A foreign government talent recruitment program is defined as an effort directly or indirectly organized, managed, or funded by a foreign government to recruit science and technology professionals or students (regardless of citizenship or national origin, and whether having a full-time or part-time position). Some foreign government-sponsored talent recruitment programs operate with the intent to import or otherwise acquire from abroad, sometimes through illicit means, proprietary technology or software, unpublished data and methods, and intellectual property to further the military modernization goals and/or economic goals of a foreign government. Many, but not all, programs aim to incentivize the targeted individual to physically relocate to the foreign state for the above purpose. Some programs allow for or encourage continued employment at U.S. research facilities or receipt of federal research funds while concurrently working at and/or receiving compensation from a foreign institution, and some direct participants not to disclose their participation to U.S. entities. Compensation could take many forms, including cash, research funding, complimentary foreign travel, honorific titles, career advancement opportunities, promised future compensation, or other types of remuneration or consideration, including in-kind compensation.

[8] Currently, the list of countries of risk includes Russia, Iran, North Korea, and China.

Implementation Phase

At the conclusion of the Implementation Phase, DOE will award eight prizes.

Faculty Implementation Prize: The top three proposals will be awarded $25,000 for first place, $15,000 for second place and $10,000 for third place. Five additional entries will be awarded $2,000 each as runner-up. A letter will also be sent to each winner's institution on behalf of DOE announcing the prize award.

What Faculty Submit

Interest Registry Form

- Name.
- Name of Institution.
- Email of Faculty.

Explore Phase

- **A project title and short summary** of the proposal (no more than 250 words).
- **A single slide that summarizes the proposal** for integrating or expanding the topics of energy technology commercialization and entrepreneurship into the faculty's institution and the potential impact should it succeed.
- **A three-page written document** addressing the suggested content shown in Table 10.
- **A completed entry form** on HeroX with answers to all required questions, including institutional demographics.
- **Resume or CV** that includes a summary of experience with teaching entrepreneurship, energy, technology commercialization, technology transfer, licensing, or similar topics. Comprehensive prior experience is not required. This information is used to ensure a diversity of perspectives are included in the program.

Implementation Phase

- **A project title and short description** of the proposal (no more than 350 words).
- **An implementation plan** (up to 10 pages) addressing the suggested content shown in Table 12. Submissions may include figures as appropriate.
- **Letter or letters of support** from department and/or institutional leadership supporting the proposal and the implementation plan.
- **Resume or CV** that includes a summary of experience with teaching entrepreneurship, energy, technology commercialization, technology transfer, licensing, or similar topics. Comprehensive prior experience is not required. This information is used to ensure a diversity of perspectives are included in the program.
- **A completed entry form** on HeroX including answers to all required questions, including institutional demographics.

How Faculty Explorers Are Determined

As part of their registration, faculty provide information about their current teaching activities and submit an initial proposal for how they will create opportunities for students to be exposed to energy technology commercialization and energy entrepreneurship activities. Proposals should articulate the realistic anticipated positive impact that incorporation of the proposed activities are likely to have on the student population.

The Prize Administrator screens all completed Explore Phase submissions received by the deadline and, in consultation with DOE, assigns eligibility. The Prize Administrator will then assign expert reviewers to independently score the content of each submission.

Faculty Explorers will be announced by January 19, 2024, and within 30 days following the announcement, the Prize Administrator will work with winners to collect the necessary information to distribute cash prizes.

How Judges Score the Faculty Explore Phase

A panel of judges will evaluate the faculty teams using the statements given in Table 10 based on the submissions received by the deadline. Following review of the submission packages, judges will meet to determine which teams will be selected as Faculty Explorers. Scores will not be shared with any of the teams. Each bullet listed in the Explore Phase evaluation statements will receive 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 9.

Table 9: Scoring Scale

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

Faculty Explore Phase Content and Evaluation Statements

For the Explore Phase, teams will indicate their interest, existing activities, and an initial proposal for the development and implementation of new educational activities relating to energy technology commercialization and entrepreneurship. The judging panel will evaluate the teams using the evaluation statements in Table 10.

A panel of expert judges will evaluate, score, and comment on each submission. The evaluation statements have equal weight, the final score from an individual judge for a submission package equals the sum of the scores for all the statements. All judges' scores are then averaged for a final score for the submission package.

This prize seeks to encourage inclusivity and diversity, commercialization of DOE national lab technology, and the pursuit of a broad mix of approaches. Before making the final awards, judges will assess the proposals against these dimensions. The final determination of winners by the Prize

Administrator will consider reviewer scores, reviewer deliberation, and program policy factors listed in Appendix A – Additional Terms and Conditions.

Table 10: Registration Submission Content and Evaluation Statements

Faculty Registration Submission Evaluation Statement for Explore Phase	
Suggested Content: • Why are you applying to this program and why do you believe that your proposed educational activities will benefit students and your home institution? • How do you see your proposed activities fitting into and complementing current program(s) and student pathways at your accredited institution? • What are the foreseen challenges of implementing your proposed activities into existing program(s) and student pathways within the department/division? • Describe the level of commitment from your department and leadership for developing and implementing your proposed educational activities.	**Evaluation Statement:** • The faculty clearly articulated a credible interest, identified an unmet opportunity at their home institution for the proposed materials, and provided a convincing understanding of the likely benefit to students at their home institution. A vision for the role their plan could play in an equitable energy transition was evident. • The faculty articulated a clear understanding of the current program structure as well as the constraints and flexibility of student pathways leading to program/degree completion requirements. The response considered what would be necessary to achieve success, understands the learning objectives, and summarized the potential impact. • The faculty did not shy away from citing realistic challenges for the implementation of the proposed learning materials within boundaries of existing course(s), department/division/program. • The faculty secured and provided clear and convincing evidence of support from department and/or relevant academic leadership for the development and implementation of the proposed education activities.

How Implementation Phase Faculty 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 with independently scoring 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 Implementation Phase final judge, a representative of OTT, will make final selection of winners based on the Implementation Phase expert reviewer's scores and comments as well as the program policy factors described in these rules. Winners will be announced as part of the National Pitch Event.

How We Score the Implementation Phase

A panel of expert reviewers will read, score, and comment on each submission. Each bullet listed in the Implementation Phase evaluation statements receives a score from 1 to 6. The bullets have equal weight, so categories that have more review criteria 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 reviewers' scores are then averaged to determine the final score for the submission package. The Implementation Phase final judge will consider reviewer scores when deciding the winners.

This prize seeks to encourage inclusivity and diversity, commercialization of national laboratory technology, and the pursuit of a broad mix of approaches. Before making the final selections/awards, reviewers will assess the proposals against these dimensions. The final determination of winners will consider reviewer scores, reviewer deliberation, and program policy factors listed in Appendix A – Additional Terms and Conditions.
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Table 11: Scoring Scale

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

Implementation Phase Content and Evaluation Statements

DOE is very interested in learning how faculty can implement educational activities focused on energy technology commercialization and entrepreneurship at their institutions. For the Implementation Phase, faculty (or faculty teams) submit a comprehensive implementation plan that leverages DOE resources provided in the Develop Phase. The evaluation statements for the Implementation Plan are outlined in Table 12. Successful teams will demonstrate a clear understanding of this opportunity, challenges, the extent of the institution's current learning opportunities, and a convincing plan for implementation. Teams will be judged based on the extent to which the judging panel agrees with the evaluation statements. Winners are determined based on the quality and innovativeness of the plan itself as well as the potential impact of implementation.

The content provided by faculty in the Implementation Phase is expected to inform a toolkit. The toolkit will be developed by DOE following the conclusion of this competition. The toolkit will be designed to potentially help other faculty across the nation that are interested in building entrepreneurship and commercialization activities at their institutions.

Table 12: Faculty Implementation Phase Content and Evaluation Statements

1. Analysis of Need	
Suggested Content: ● What are the current demographics of your institution? ● What are the existing relevant activities, programs and/or coursework related to commercialization and entrepreneurship? ● What is the scope of the student body that you plan to include in these activities (e.g., graduate, undergraduate, departments or schools within your home institution)?	**Evaluation Statement:** ● The response provides basic demographic information for the home institution. The response conveys an understanding of the academic landscape within and across their institution and demonstrates a clear understanding of current activities around commercialization and entrepreneurship.
2. Actionability	
Suggested Content: ● What are the educational activities that you are proposing and how will it support the learnings of students in commercialization and entrepreneurship? ● What resources do you need to implement this proposed activity and do you have them? ● How could U.S. Department of Energy tools like ARLs, Pathways to Commercial Liftoff, Lab Partnering Service or others be potentially implemented in your proposal?	**Evaluation Statement:** ● The response provided high-quality and complete content that is likely to be implementable, impactful and sustainable at their own institution. The submitted material was aligned with expected learning objectives could also be valuable to other U.S. collegiate institutions considering similar efforts. ● The materials clearly and meaningfully incorporated ARLs into the content and also indicated relevant connections to the Pathways to Commercial Liftoff Reports and/or other DOE provided resources.
3. Support	
Suggested Content: ● What hurdles need to be cleared for the idea to be implemented (e.g., for a new course is there an internal committee that needs to approve the course before it is part of the official school course offerings)? ● What support has been established for the proposal as presented including	**Evaluation Statement:** ● The submission has provided clarity on the potential institutional hurdles that need to be overcome for implementation. ● There is clear and credible support from institutional leadership for this proposal and where applicable, support to overcome any hurdles. The submitted materials have

<table>
<tr><td>letters of support to help overcome any hurdles?</td><td>provided evidence that their proposals are in alignment with institutional priorities.</td></tr>
<tr><td colspan="2">4. Potential Impact</td></tr>
<tr><td>Suggested Content:
How is success defined?
How will success be measured?
How will students benefit if this proposal were to succeed?
Could other institutions leverage what you have developed and if so, how?</td><td>Evaluation Statement:
The proposed plan clearly addresses the learning opportunities and needs of its intended student population.
The project provided high-quality and complete content that is likely to be incorporated and valuable for sustained use at their own institution.
Additional degrees of success could be deemed likely through broader impacts if the project materials could be disseminated and implemented at other institutions considering similar efforts.</td></tr>
<tr><td colspan="2">5. Overall Implementation Plan</td></tr>
<tr><td>Suggested Content:
What is the timeline and rough stages of implementation?
How will this be implemented? What resources do you need for implementation? Do you have them? If not, what is your plan for obtaining the resource levels that you need?
How can DOE best support the program in future years? (e.g., guest speakers, judges for prizes)</td><td>Evaluation Statement:
There is sufficient information to enable successful implementation, a clear timeline for implementation and clarity on the resources needed to successfully implement the proposal at the institution. Resources exist or there are ideas on how to get those resources and ideas on how DOE can be involved are included.</td></tr>
</table>

Appendix A – Additional Terms and Conditions

Universal Contest Requirements

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

- Faculty competitors agree to release their Submission Package 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.

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 markets
- Whether the proposed business plan ideas have received an investment of $200,000 or more and/or have won a pitch competition in the amount of $20,000 or more. The purpose of this contest is to foster the development of new ideas.

- 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 addresses one or some of the Justice40 priorities.
- 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.

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.

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.

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.

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 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.

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.

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.

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.

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.

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.

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.

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.

DOE may conduct a risk review, using Government resources, of the competitor and project personnel for potential risks of foreign interference. The outcomes of the risk review may result in the submission being eliminated from the prize competition. This risk review, and potential elimination, can occur at any time during the prize competition. An elimination based on a risk review is not appealable.

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.

National Environmental Policy Act (NEPA) Compliance

DOE's administration of this prize is subject to NEPA (42 USC 4321, et seq.). NEPA requires federal agencies to integrate environmental values into their decision-making processes by considering the potential environmental impacts of their proposed actions. For additional background on NEPA, please see DOE's NEPA website, at http://nepa.energy.gov/.

While NEPA compliance is a federal agency responsibility and the ultimate decisions remain with the federal agency, all participants in this prize will be required to assist in the timely and effective completion of the NEPA process in the manner most pertinent to their participation in the prize competition. Participants may be asked to provide DOE with information on their planned activities such that DOE can conduct a meaningful evaluation of the potential environmental impacts.

Return of Funds

As a condition of receiving a prize, competitors agree that if the prize was awarded based on fraudulent or inaccurate information provided by the competitor to DOE, DOE has the right to demand that any prize funds or the value of other non-cash prizes be returned to the government.

Appendix B – Technology Office Bonus Prize Resource Documents

Building Technologies Office Bonus Focus: 120V Heat Pump Water Heaters

Statement of Interest

The Biden administration set a goal to decarbonize the U.S. built environment by 2050. To meet this goal, the nation must address its existing, aging building stock, including the electrification of commercial and residential heating, ventilating, and air conditioning (HVAC) systems. Therefore, DOE's Building Technologies Office (BTO) is challenging you to develop innovative business model(s) or commercialization plan(s) to increase the adoption of electrification solutions for commercial and/or residential HVAC systems.

Bonus Challenge

Develop innovative business model(s) or commercialization plan(s) to increase the adoption of electrification solutions for commercial and/or residential HVAC technologies that increase market adoption and address industry challenges.

Evaluation Statement

The entry demonstrates a clear understanding of the technology and market potential for electrification solutions for commercial and/or residential HVAC technologies and presents innovative business model(s) or commercialization plan(s) to increase market adoption and address industry challenges. The entry can be multifaceted and can propose solutions for both the commercial and residential sectors. The business model(s) or commercialization plan(s) must identify, outline, and address challenges unique to each market sector.

Content

Introduction

President Biden has set a goal for the United States to achieve net-zero emissions by 2050.[9] Electrifying residential and commercial buildings will be part of that solution, with residential and commercial buildings accounting for approximately 29%---or about 21 quadrillion British thermal units (Btu)—of the county's total end-use energy consumption.[10] Although there is a growing demand for heat pumps, natural-gas-fired heating equipment, such as furnaces and boilers, accounts for the

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[9] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

[10] https://www.eia.gov/tools/faqs/faq.php?id=86&t=1

largest share of energy consumption for space heating in residential and commercial buildings.[11] The U.S. Energy Information Administration (EIA) conducts a survey of households and commercial businesses each year to measure energy use. The EIA reported that over half (52%) of an American household's energy use in 2020 went to air conditioning and space heating.[12] Space heating accounted for nearly one-third (32%) of energy use in commercial buildings in 2018 (the most recent year for which data is available), whereas cooling accounted for 9% of the 6,787 trillion Btu consumed by commercial buildings in the United States in 2018.[13]

To electrify and decarbonize the U.S. building stock, natural-gas-fired equipment in residential and commercial buildings can be replaced with electric alternatives and coupled with wind and/or solar power. However, the cost and complexities of whole-building electrification can be a barrier that slows widespread adoption. Low-and moderate-income households are particularly vulnerable to the upfront costs associated with whole-home electrification. Similarly, newer, larger, more energy-intensive owner-occupied commercial buildings are better positioned to take on the upfront costs of electrification than small and medium commercial properties.[14] Therefore, these energy and cost saving technologies are unlikely to diffuse rapidly into the rest of the commercial building stock. This is especially true for small and medium commercial buildings in disadvantaged communities,[15] older buildings, and buildings in cold climates.[16]

BTO is challenging you to develop an innovative business model(s) or commercialization plan(s) to increase the adoption of electrification solutions for HVAC technologies in residential and/or commercial buildings in all climate zones.

Technology Overview

Heat pumps are an efficient electric technology for space heating and cooling that can replace traditional air conditioners and heating systems. Heat pumps are more efficient than other forms of heating and cooling because they transfer heat rather than generate it. The most common type of heat pump is an air-source heat pump, which moves heat between a building and the surrounding outside air. Most air-source heat pumps can deliver as much as three times as much energy in heat as the electrical energy required for the process.[17]

When properly installed, air-source heat pumps can reduce electricity use for space heating and cooling by up to 65% compared to electric resistance heating with furnaces or baseboards.[18] High-efficiency heat pumps also dehumidify the air better than standard central air conditioners, resulting in less energy use and more cooling comfort in the summer months. Air-source heat pumps have many design options. They may be connected to ducts or be ductless, be single-zone or multi-zone, and be split or packaged systems. Most heat pumps have two main components—an outdoor

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[11] https://www.eia.gov/outlooks/aeo/narrative/index.php#TechnologicalAdvancement
[12] https://www.eia.gov/energyexplained/use-of-energy/homes.php
[13] https://www.eia.gov/consumption/commercial/
[14] https://www.energy.gov/sites/default/files/2023-05/bto-peer-2023-methodology-defining-affordability-underserved-nrel-clarke.pdf
[15] https://www.energy.gov/diversity/justice40-initiative
[16] https://www.nrel.gov/docs/fy22osti/82346.pdf
[17] https://www.energy.gov/energysaver/air-source-heat-pumps
[18] https://www.energy.gov/energysaver/heat-pump-systems

compressor/condenser and an indoor air-handling unit—with a conduit linking the two units that typically includes a power cable, refrigerant, suction tubing, and condensation drain.

Heat pumps require enough space to ensure 400–500 cubic feet per minute (cfm) of airflow per ton of heat pump air conditioning capacity to operate properly. Heat pump efficiency suffers if airflow drops below 350 cfm per ton.[19] Heat pumps can also have performance issues with incorrect refrigerant charge. Because packaged systems are charged in the factory, incorrect refrigerant charge is more typically an issue with split systems, which are charged at the time of installation. Refrigerant charge should be checked at the annual service call.

Costs

There are two costs to consider when comparing heat pumps to other HVAC systems. The first is the upfront cost of installing the technology, and the second is the cost of maintaining and operating it. Many factors influence the cost of a heat pump installation. These factors are even greater in commercial applications than in residential ones. The size of the building or home, type of heat pump system, regional climate, whether a backup heating system is needed, and the condition of existing ducts all impact the final installation cost. Improving the energy efficiency of the building prior to sizing and installing a heat pump will reduce the heating and cooling loads of the building and therefore reduce the size (and cost) of the heat pump system needed.

Federal rebates and incentives made available through the Inflation Reduction Act, local utility programs, and other financing options reduce the upfront costs of installing heat pumps. For low-income households with less than 80% of the area median income, electrification rebates cover 100% of the cost of heat pump installation up to $8,000. For moderate-income households (between 80 and 150% of Area Median Income), the rebates cover half of the heat pump installation costs up to $8,000. [20] Federal tax credits are available to all Americans wishing to increase the efficiency of their homes and commercial properties.

The average life expectancy of a heat pump is around 15 years. An American household may save more than $500 per year by switching to a heat pump, depending on the size of the home, the local climate, and the energy efficiency of the building envelope.[21] Annual service calls to maintain a heat pump system typically cost between $100 and $200.[22] It is important to understand the utility rates for natural gas (or other heating fuel) and electricity if switching from one fuel to electricity.

Market Opportunity

Analysts sized the global heat pump market at $65 billion in 2021 with a projected a compound annual growth rate of 9% from 2022–2032.[23] The U.S. market was sized at nearly $10 billion in

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[19] https://www.energy.gov/energysaver/air-source-heat-pumps
[20] https://www.rewiringamerica.org/app/ira-calculator/information/high-efficiency-electric-home-rebate-heehra
[21] https://www.energy.gov/articles/pump-your-savings-heat-pumps
[22] https://www.forbes.com/home-improvement/hvac/heat-pump-maintenance-service-%20cost/?sh=2e0ae72a1b50
[23] https://www.factmr.com/report/3763/heat-pump-market

2021 and is predicted to see a 9.4% compound annual growth rate over the next 5 years.[24] Analysts believe that the residential sector will dominate the U.S. heat pump market over the next decade.[25]

There are 120 million housing units across the United States. A 2020 study conducted by Rocky Mountain Institute shows that replacing a gas furnace with a heat pump can reduce carbon emissions in 99% of U.S. households.[26] However, the market opportunity for heat pumps varies by region due to climate, technology availability, and the cost of natural gas and electricity. As of 2020, over 17 million housing units had a heat pump installed, accounting for over 50% of all residential heating equipment sales in the United States.[27]

In November 2023, the Biden administration announced $169 million in funding to accelerate the manufacturing of electric heat pumps as part of its Investing in America Agenda. A portfolio of projects across 13 states will manufacture electric heat pumps and key components (compressors and refrigerants) while creating 17,000 jobs and expanding equipment availability nationwide.[28]

Despite these impressive strides, awareness about the benefits of heat pumps and the technical skills needed to install the equipment remain low in the U.S. market. Overcoming these barriers and developing innovative business models to address the upfront costs of heat pumps are needed to promote the widespread adoption of heat pumps in the United States.

Additional Resources

- DOE – Heat Pump Systems
  https://www.energy.gov/energysaver/heat-pump-systems
- Energy Star – How Does a Heat Pump Work?
  https://www.energystar.gov/products/ask-the-experts/how-does-a-heat-pump-work
- EIA – Residential Energy Consumption Survey
  https://www.eia.gov/consumption/residential/index.php
- EIA – Commercial Building Energy Consumption Survey
- https://www.eia.gov/consumption/commercial/
- The Cost of Decarbonization and Energy Upgrade Retrofits for US Homes
  https://eta-publications.lbl.gov/sites/default/files/final_walker_-_the_cost_of_decarbonization_and_energy.pdf
- Rocky Mountain Institute – The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings
  https://rmi.org/insight/the-economics-of-electrifying-buildings/

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24 https://www.mordorintelligence.com/industry-reports/united-states-heat-pump-market
25 https://www.factmr.com/report/3763/heat-pump-market
26 https://rmi.org/its-time-to-incentivize-residential-heat-pumps/#:~:text=The%20United%20States%20has%20made,fossil%20fuel%20use%20in%20building
27 https://www.energy.gov/articles/pump-your-savings-heat-pumps
28 https://www.energy.gov/articles/biden-harris-administration-announces-169-million-accelerate-electric-heat-pump

Geothermal Technologies Office Bonus Focus: Innovation and Inclusiveness

Statement of Interest

Geothermal energy, along with the 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. Geothermal energy has the highest capacity factor (>90%) among renewable energy sources, making it an invaluable component of electricity grid stabilization and load balance. DOE's Geothermal Technologies Office (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.

Bonus Challenge

DOE's Geothermal Technologies Office is challenging you to develop an innovative business model for a novel geothermal technology of your choice that tackles emerging challenges in the geothermal industry and aims to improve the performance, affordability, reliability, and value of geothermal energy and/or heat in the United States. The business model goal should be to increase the adoption of new geothermal technologies and maximize the performance and/or reduce the costs of the components, installation, and operation of geothermal energy and heat systems.

Evaluation Statement

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

Content

Introduction

Geothermal energy is heat derived from below the Earth's surface that can be harnessed as a carbon-free, renewable energy source with a small physical footprint around the clock. Geothermal is cosmic in origin—as opposed to atmospheric, such as wind or water—and will be constant, non-intermittent, and abundant in supply for as long as the Earth exists. It is an always-on source of secure, reliable, and flexible domestic energy that can be utilized across industrial, commercial, and residential sectors. Geothermal energy can also offer important benefits to the nation, including grid stability, a greater diversity of affordable energy options, and efficient heating and cooling.

As identified in the *GeoVision* analysis,[29] the high costs and risks associated with geothermal exploration are a major barrier to expanded development of the nation's undiscovered, or "hidden,"

[29] www.energy.gov/geovision

hydrothermal resources. Similarly, successful development of enhanced geothermal system 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 by 2050, representing 60 gigawatts-electric (GWe) of electricity generation capacity.
- The market potential for geothermal heat pump 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 GWe by 2050—more than double the 6 GWe 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 utilizes the hot water that already exists in hot springs and geothermal reservoirs near the surface of the Earth, producing heat directly from that hot water to heat and cool buildings, homes, and communities. Lower-temperature resources can also support other direct-use geothermal 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 target space or process.
- A disposal system—an injection well, storage pond, or river—to receive the cooled geothermal fluid (this does not apply to systems with "closed loops" where the fluid circulates continuously in the piping).

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,[30] 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 Appalachia region is also a promising candidate for direct-use geothermal.

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[30] www.energy.gov/geovision

Geothermal district heating and cooling (GDHC) systems with a variety of 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°F–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 CO_2 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

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. Although 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.

Geothermal heat pumps take advantage of seasonal variation by transferring heat stored in the Earth or in groundwater into buildings during the winter and transferring heat out of buildings 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 producing 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 states and U.S. territories. Geothermal heat pumps are a particularly good option for those who are building a new home or planning a major renovation to an existing home by replacing, for example, a heating, ventilating, and air conditioning system.

Geothermal heat pumps come in four types of systems that loop the heat to or from the ground and a house. Three of these—horizontal, vertical, and pond/lake—are closed-loop systems. The fourth is an open-loop system. Choosing the one that is best for a given 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 constructions 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 body of water, this may be the least expensive option. A supply line pipe runs underground from the building to the water and coils in circles at least 8 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. 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,[31] 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.[32] That is 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.
- 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

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[31] www.energy.gov/geovision

[32] 2021 U.S. Geothermal Power Production and District Heating Market Report (nrel.gov)

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 in turn produces electricity. The steam eliminates the need to burn fossil fuels to run the turbine, and it 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 were the first type of geothermal power generation plant built (they were first used at Larderello in Italy in 1904).[33] Steam technology is still effective today and is 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 plant 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 ("binary") fluid with a much lower boiling point than 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 into the atmosphere. Because geothermal resources below 300°F are most common, 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 GTO to assess geothermal deployment potential. The report states that geothermal electricity generation capacity in the United States has the potential to increase to more than 60 GW by 2050 (8.5% of all U.S. electricity generation).
- 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 who are funded by GTO. The GDR is powered by OpenEI, an energy information portal sponsored by DOE and developed by the National Renewable Energy Laboratory in support of the Open Government Initiative to make energy data transparent, participatory, and collaborative.

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

- Office of Scientific and Technical Information (OSTI): DOE's OSTI database contains more than 70 years of energy-related research results and citations, consisting of nearly 3 million citations.
- Stanford/International Geothermal Association 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 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 United States and known geothermal resource areas and exploration regions, including state geothermal maps, potential for enhanced geothermal systems, 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, hydropower, 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 Oregon Renewable Energy Center of the Oregon Renewable Energy Center.

Hydrogen and Fuel Cell Technologies Office Bonus Focus: End User Hydrogen Adoption

Statement of Interest

The U.S. clean hydrogen market is poised for rapid growth, accelerated by Hydrogen Hub funding, multiple tax credits, DOE's Hydrogen Shot, and decarbonization goals across the public and private sectors. DOE's National Clean Hydrogen Strategy and Roadmap has identified the potential for up to 10 million metric tonnes (MMT)/year of clean hydrogen production by 2030, 20 MMT/year by 2040, and 50 MMT/year by 2050. Achieving these goals could enable a ~10% reduction in U.S. greenhouse gas emissions by 2050, particularly in sectors that are difficult to decarbonize via traditional approaches, such as industrial/chemical uses and heavy-duty transportation.[34] Achieving commercial liftoff will enable clean hydrogen to play a critical role in the nation's decarbonization strategy.

Bonus Challenge

The Hydrogen and Fuel Cell Technologies Office (HFTO) challenges you to develop innovative business models to accelerate clean hydrogen and fuel cell technology adoption in the United States. Examples of sectors where hydrogen has the opportunity for growth are described in the National Clean Hydrogen Strategy and Roadmap, and in the Pathways to Commercial Liftoff: Hydrogen report[35].

Evaluation Statement

The presentation demonstrates a well-reasoned and well-articulated understanding of the chosen technology, market potential, and sector.

Content

Introduction

Hydrogen is the most abundant element in the universe; however, it is rarely found in its elemental form on Earth. It must be produced from a hydrogen-containing feedstock (e.g., water, biomass, fossil fuels, or waste materials) using an energy source. Once hydrogen has been produced, it can be used to store, move, and deliver low- or no-carbon energy where it is needed. Hydrogen can be stored as a liquid, gas, or chemical compound, and is converted to energy via traditional combustion methods (in engines, furnaces, or gas turbines), electrochemical processes (in fuel cells), and hybrid approaches (such as integrated combined-cycle gasification and fuel cell systems). It is also used as a feedstock or fuel in a number of industries, including petroleum refining, ammonia production, food and pharmaceutical production, and metals manufacturing. Hydrogen can be produced in large

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[34] U.S. National Clean Hydrogen Strategy and Roadmap (energy.gov)
[35] The Pathway to: Clean Hydrogen Commercial Liftoff (energy.gov)

centralized production facilities or in smaller distributed production facilities, and can be transported via truck, pipeline, tanker, or other means.[36]

Hydrogen, as a versatile energy carrier and chemical feedstock, offers advantages that unite all our nation's energy resources—renewables, nuclear, and fossil fuels. It also enables innovations in energy production and end uses that can help decarbonize three of the most energy-intensive sectors of our economy: transportation, electricity generation, and manufacturing.[37]

Technology Overview

DOE's Hydrogen Program Plan lists the following as technology focus areas:

Hydrogen Production

The United States has diverse and abundant natural resources to enable secure, clean, sustainable, large-scale, and affordable carbon-neutral hydrogen production. Global demand for hydrogen across sectors is increasing, with current worldwide consumption at approximately 70 MMT per year.[38] Of this, the United States currently produces and consumes almost 10 MMT annually, equivalent to just over 1 quadrillion British thermal units per year (1% of U.S. energy consumption).[39]

To meet this growing demand, a broad portfolio of hydrogen production pathway technologies are being explored and developed. These include technologies for tapping into fossil resources with carbon capture, utilization, and storage; extracting hydrogen from biomass and waste stream resources; and splitting water. This wide range of options opens regional opportunities to expand the hydrogen supply base across the country, offering carbon-neutral hydrogen production capacities from a few hundred to hundreds of thousands of kilograms per day.[40]

Hydrogen Delivery

To support a wide range of applications, delivery infrastructure for hydrogen may incorporate multiple technology pathways capable of transporting hydrogen in various forms, including as a gas in pipelines and high-pressure tube trailers, as a liquid in tanker trucks, and using chemical hydrogen carriers. Different technologies for dispensing hydrogen may also be needed, depending on how the hydrogen is transported, stored, and utilized. The technologies required to support these delivery pathways are at various stages of development, but they must ultimately be both affordable and meet or exceed the level of safety, convenience, reliability, and energy efficiency expected from existing infrastructure for other fuels.[41]

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[36] U.S. Department of Energy. November 2020. *Department of Energy Hydrogen Program Plan*. Page 4. https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/hydrogen-program-plan-2020.pdf.
[37] U.S. Department of Energy. November 2020. *Department of Energy Hydrogen Program Plan.* https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/hydrogen-program-plan-2020.pdf.
[38] U.S. Department of Energy. October 2019. Hydrogen and Fuel Cells Program Record 19002. "Current Hydrogen Market Size: Domestic and Global." https://www.hydrogen.energy.gov/pdfs/19002-hydrogen-market-domestic-global.pdf.
[39] Ibid
[40] U.S. Department of Energy. November 2020. *Department of Energy Hydrogen Program Plan.* https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/hydrogen-program-plan-2020.pdf.
[41] Ibid

Hydrogen Storage

Hydrogen has nearly three times the energy content of gasoline per unit of mass,[42] but the volumetric energy density of gaseous hydrogen is low, making it difficult to store in compact containers. To overcome this challenge, hydrogen is usually stored using physical processes, as a gas or cryogenic liquid; it can also be stored using material-based processes that incorporate hydrogen in chemical compounds.[43]

Conversion

Hydrogen is an energy carrier that is produced using energy and feedstocks such as water, biomass, natural gas, coal, oil, and wastes such as wastewater and plastics. To be useful, the energy carried by hydrogen must be converted into a different form, such as electricity or heat. This conversion can be accomplished through combustion using turbines or reciprocating engines, or through an electrochemical process using a fuel cell. There are several opportunities to design hybrid energy systems, for example, using high- or low-temperature stationary fuel cells integrated with gas turbines in large-scale combined-cycle hybrid systems, which use both conventional and fuel cell energy conversion technologies.[44]

Applications

Hydrogen has the potential for use in diverse applications across multiple sectors, where it can provide substantial environmental and economic benefits as well as improved energy security and resiliency. Large amounts of hydrogen can be used in the transportation, power generation, and industrial and manufacturing sectors, which can enable economies of scale and support a robust domestic supply chain. Integrated energy systems, which can span sectors, offer additional opportunities by using hydrogen as an energy carrier to improve the economics of existing and emerging electric power generation systems.[45]

Strategies That Enable Benefits of Clean Hydrogen[46]

The US National Clean Hydrogen Strategy and Roadmap is based on ***prioritizing three key strategies*** to ensure that clean hydrogen is developed and adopted as an effective decarbonization tool for ***maximum benefit*** to the United States:

Target strategic, high-impact uses for clean hydrogen.

This will ensure that clean hydrogen is utilized in the highest-value applications, where limited deep decarbonization alternatives exist. Specific markets include the industrial sector (e.g., chemicals, steel, and refining), heavy-duty transportation, and long-duration energy storage to enable a clean

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42 The energy content of hydrogen is 33 kWh/kg, while the energy content of gasoline is 12 kWh/kg, based on lower heating value.
43 U.S. Department of Energy. November 2020. *Department of Energy Hydrogen Program Plan.* https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/hydrogen-program-plan-2020.pdf.
44 Ibid
45 Ibid
46 U.S. Department of Energy. 2023. *U.S. National Clean Hydrogen Strategy and Roadmap.* https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf

grid. Additional longer-term opportunities include exporting clean hydrogen or hydrogen carriers and enabling energy security for our allies.[47]

Reduce the cost of clean hydrogen.

The Hydrogen Energy Earthshot (Hydrogen Shot) launched in 2021 will catalyze both innovation and scale, stimulating private-sector investments, spurring development across the hydrogen supply chain, and dramatically reducing the cost of clean hydrogen. Efforts will also address critical material and supply chain vulnerabilities and designs for efficiency, durability, and recyclability. Together with investment in midstream infrastructure (storage, distribution), these initiatives can reduce not only the production, but also the delivered cost, of clean hydrogen.[48]

Focus on regional networks.

Investing in and scaling Regional Clean Hydrogen Hubs will enable large-scale clean hydrogen production close to high-priority hydrogen users, allowing the sharing of a critical mass of infrastructure. Also, these investments will drive scale in production, distribution, and storage to facilitate market liftoff. Properly implemented, these regional networks will create place-based opportunities for equity, inclusion, and sustainability. Priorities will include reducing environmental impacts, creating jobs—including good-paying union jobs—securing long-term offtake contracts, and jumpstarting domestic manufacturing and private-sector investment.[49]

Additional Resources

- Pathways to Commercial Liftoff: Clean Hydrogen
- DOE Hydrogen and Fuel Cell Technologies Office
- DOE Office of Clean Energy Demonstration - Regional Clean Hydrogen Hubs
- DOE Hydrogen Shot
- DOE National Renewable Energy Laboratory - Hydrogen and Fuel Cells
- DOE Lawrence Berkeley National Laboratory - Hydrogen
- DOE National Energy Technology Laboratory - Natural Gas Decarbonization and Hydrogen Technologies Program

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47 Ibid
48 Ibid
49 U.S. Department of Energy. 2023. *U.S. National Clean Hydrogen Strategy and Roadmap.* https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/us-national-clean-hydrogen-strategy-roadmap.pdf

Office of Electricity Bonus Focus: Grid-Enhancing Technologies

Statement of Interest

Grid-enhancing technologies (GETs) have been identified as a way to maximize the transmission of electricity through the power system. These technologies can be used in the near term to defer larger infrastructure investments and reduce overall power grid congestion, which protects consumers from higher electricity costs

Bonus Challenge

DOE's Office of Electricity is challenging you to develop innovative models to increase the adaption of GETs to benefit the U.S. power grid.

Evaluation Statement

The presentation captures a clear understanding of GETs and the market potential for GETs to be implemented by various utility entities—regional transmission operators (RTOs), independent system operators (ISOs), wind plant developers, etc.—in a way that decreases congestion and reduces electricity costs.

Content

Introduction

A modern grid requires modern infrastructure, including new devices enabled by digital technology or simply new paths for electricity to flow. GETs can be used to reduce congestion across the existing electricity transmission system through a range of technologies, including sensors, power flow control devices, and analytical tools. GETs can be used to enhance transmission operations and improve planning, as well as to provide benefits for N-1 contingency cases for utilities.[50]

Technology Overview

GETs fall into a number of different categories of technologies that can benefit grid reliability.

Dynamic line ratings (DLRs) are a set of methods for determining conductor ratings using current or forecasted conditions. DLRs utilize the same calculations from the IEEE 738 standard,[51] but use time-varying components instead of static ratings, which make conservative assumptions about weather as constant for a seasonal basis. DLR systems are typically either weather-based systems or asset-based systems that measure the conductor state directly. One subset of DLR methods includes ambient adjusted ratings, where the static assumptions for wind and solar are still used,

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[50] U.S. Department of Energy. "Grid-Enhancing Technologies: A Case Study on Ratepayer Impact." February 2022.

[51] IEEE 738, Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors. 2012.

but the ambient temperature used in the IEEE 738 calculations is allowed to change with local weather conditions. Idaho National Laboratory has led several projects funded by the Wind Energy Technologies Office over the years in weather-based DLR and has peer-reviewed relevant publications.[52, 53, 54] In general, transmission corridors can be positively impacted through DLR, but the degree to which ampacity is available varies widely between regions, and weather pattern relations to static assumptions need to be studied on a case-by-case basis. An overview of other DLR-type approaches can be found in the DOE report led by Idaho National Laboratory.[55]

Power flow controllers (PFCs) can balance overloaded lines with underutilized transmission corridors within a transmission network. Some PFCs work by adjusting the impedance of the transmission lines, which can allow utilities to push power to avoid congested lines or pull power into underutilized transmission corridors.

Topology optimization is a set of software solutions for automatically finding ways to reroute flow around congested or overloaded facilities. Technology optimization takes advantage of the meshed nature of the overall power grid, and typically, the reconfigurations adjust the high-voltage circuit breakers to distribute electricity flow more evenly across the network.

Although other technologies can help with the transmission lines, other limitations in the electricity transmission systems exist. Transformers can remain a limitation, as they adjust voltages in the system. The IEEE/American National Standards Institute C57.91 provides a standard for guidance on transformer ratings.[56] Dynamic transformer ratings can be used to provide additional transformer capacity to prevent congestion, if local weather conditions allow for limiting the thermal impact on the asset health.

Costs

In a 2018 DOE report, the sum of real-time congestion costs among the major system operators was calculated to be $4.8 billion.[57] In California between 2009 and 2017, the increase in congestion-related costs reflected on ratepayers' bills was $683 million.[58] Standard transmission expansion projects can be quite costly, and have totaled more than $20 billon every year between 2014 and

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[52] Bhattarai, B. P., Gentle, J. P., McJunkin, T., Hill, P. J., Myers, K. S., Abboud, A. W., Renwich, R., and Hengst, D. (2018). Improvement of transmission line ampacity utilization by weather-based dynamic line rating. IEEE Transactions on Power Delivery, 33(4), 1853-1863.
[53] Abboud, A. W., Fenton, K. R., Lehmer, J. P., Fehringer, B. A., Gentle, J. P., McJunkin, T. R., Le Blanc, K.L., Petty, M.A., and Wandishin, M. S. (2019). Coupling computational fluid dynamics with the high resolution rapid refresh model for forecasting dynamic line ratings. Electric Power Systems Research, 170, 326-337.
[54] Abboud, A. W., Gentle, J. P., McJunkin, T. R., & Lehmer, J. P. (2019). Using computational fluid dynamics of wind simulations coupled with weather data to calculate dynamic line ratings. IEEE Transactions on Power Delivery, 35(2), 745-753.
[55] U.S. Department of Energy. "Dynamic Line Rating." June 2019.
[56] IEEE PES Transformers Committee, "PES Transformers Committee," IEEE, April 2021. [Online]. Available: https://www.transformerscommittee.org/.
[57] U.S. Department of Energy, "Annual U.S. Transmission Data Review," 2018.
[58] I. Penn, "Why Wall Street gets a cut of your power bill," Los Angeles Times, 15 December 2017. [Online]. Available: https://www.latimes.com/projects/la-fi-electricity-capacity-investments/.

2016.[59] Due to the old age of most of the transmission infrastructure in the United States (established between 1960 and the 1980s), one estimate shows that the replacement costs will continue to increase by $1.2–$3.2 billion per year.[60] Line reconductoring can be a way to increase capacity on exiting transmission pathways, but can cost $1–$8 million per mile, depending on the voltage.[61]

The DOE Office of Electricity released *Grid-Enhancing Technologies: A Case Study on Ratepayer Impact*, a report focusing on the impacts of integrating GETs into existing transmission lines. The GETs case study report, led by Idaho National Laboratory, performed a top-down analysis to identify regions of the country that could benefit from GETs due to plans for increased renewable penetration combined with congested transmission line corridors. The case study narrowed in on a smaller region of western New York, which showed that DLR can reduce congestion costs by $1.7 million, and combined utilization of DLR and PFCs could reduce costs by $9.1 million at a lower cost to the ratepayer than traditional upgrades.

The nationwide overview included in the GETs study may give responders to this call regions on which they could begin to focus their own case studies. Several other studies have shown the potential cost impacts of GETs. An analysis of a hypothetical DLR installation on historically observed weather conditions showed $11.1 million in savings over the target line.[62] Another study showed that the deployment of DLR could provide congestion savings of $0.26 million in a 4-hour window, and that cost savings from utilizing topology control could range from $18–$44 million annually.[63]

A study in Minnesota, Wisconsin, and Colorado showed potential DLR increases of about 13% with an investment of $12.5 million.[64] A study by the International Renewable Energy Agency on lines in Texas showed increases of 6%–14% with an investment of $4.833 million.[65] A pilot case in the PJM utility region showed an 8.4:1 return on the investment cost of DLR with an installation cost of about $500,000.[66] A study by the Brattle Group over a range of PFCs shows that costs of $81–$137 million could be projected to save $67 million per year.

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59 U.S. Energy Information Administration, "Utility continue to increase spending on transmission infrastructure," 2018. [Online]. Available: https://www.eia.gov/todayinenergy/detail.php?id=34892.

60 J. Pfeifenberger, J. Chang and J. Tsoukalis, "Investment Trends and Fundamentals in U.S. Transmission and Electricity Infrastructure," The Brattle Group, 2015.

61 J. McCall and T. Goodwin, "Dynamic Line Rating as a Means to Enhance Transmission Grid Resilience," in CIGRE U.S. National Committee 2015 Grid of the Future Symposium, 2015.

62 J. Marmillo, N. Pinney, B. Mehraban, S. Murphy, and N. Dumitriu. "Simulating the economic impact of a dynamic line rating project in a regional transmission operator (RTO) environment." In Proc. CIGRE US Nat. Committee Grid Future Symp., pp. 1-8. 2018.

63 T. Tsuchida and R. Gramlich. The Brattle Group/Grid Strategies LLC. “Improving Transmission Operation with Advanced Technologies.” 2019.

64 National Grid. “Enabling Renewable Energy with LineVision.” 2021. https://ngpartners.com/case-study/enabling-renewable-energy-with-linevision/.

65 International Renewable Energy Agency. “Dynamic Line Rating Innovation Landscape Brief.” 2020.

66 S. Murphy and N. Dumitriu. PJM. Introduction to Dynamic Line Rating. Emerging Technologies Forum, Aug 2020.

Market Opportunity

The market opportunity for GETs may vary by region due to energy market activity and participation, climate, technology, and the cost of electricity in a particular utility/market region. A DOE study on congestion showed that costs vary widely by region, with over $1 billion each in the New York Independent System Operator (NYISO) region and PJM regions, $0.7 billion in the Midcontinent Independent System Operator (MISO) region, $0.5 billion in the California Independent System Operator (CAISO) region, and only $0.1 billion in the ISO New England (ISO-NE) region.[67] Areas with high transmission congestion that have active and saturated energy markets are expected to benefit from GETs due to high energy prices associated with transmission congestion. The benefit of some GETs, such as DLR, will also vary widely based on local weather conditions.

The values associated with GETs are not typically prioritized by transmission planning. Market participant compensation and encouragement has proved challenging in providing auxiliary services. Mechanisms and motivations have developed over time to encourage market participants to engage in auxiliary services for electricity markets, and the goal is to find and establish similar motivating mechanisms for GETs.

Flexibility and operational optimization across the year are not valued in a world where reliability planning is tantamount. The Federal Energy Regulatory Commission recently announced an Advance Notice of Proposed Rulemaking, Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection, which would formalize this consideration.[68] The incentives to leverage GETs are often misaligned with those who benefit most. Transmission owners, generation developers, utilities, independent system operators/regional transmission organizations, and clean energy advocacy groups have various primary objectives, but their primary focus is not solely on the efficient economic planning and operation of the power system. It would be beneficial to work with RTOs to provide actionable suggestions for deployment of GETs to benefit ratepayers.

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[67] U.S. Department of Energy. “National Electric Transmission Congestion Study.” September 2020.
[68] Federal Energy Regulatory Commission, "Advance Notice of Proposed Rulemaking: Building for the Future Through Electric Regional Transmission Planning and Cost Allocation and Generator Interconnection," 15 July 2021. [Online]. Available: https://www.ferc.gov/news-events/news/advance-notice-proposed-rulemaking-building-future-through-electric-regional.

Additional Resources

- https://watt-transmission.org/wp-content/uploads/2021/02/Brattle__Unlocking-the-Queue-with-Grid-Enhancing-Technologies__Final-Report_Public-Version.pdf90.pdf
- https://www.energy.gov/sites/prod/files/2019/08/f66/Congressional_DLR_Report_June2019_final_508_0.pdf
- https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf
- https://www.cmu.edu/ceic/assets/docs/seminar-files/2013-2014/heidelcmuseminarpresentation09262013.pdf
- https://www.energy.gov/sites/default/files/2020/10/f79/2020%20Congestion%20Study%20FINAL%2022Sept2020.pdf
- https://www.sciencedirect.com/science/article/pii/S0378779619300471
- https://ieeexplore.ieee.org/abstract/document/8747532
- https://ieeexplore.ieee.org/abstract/document/8269366

Office of Electricity Bonus Focus: Large Power Transformers

Statement of Interest

The Biden administration's goal to decarbonize the U.S. economy by 2050 will require substantial electrification. Increasing clean energy delivery capacity requires address our existing, aging electric sector infrastructure, including large power transformers (LPTs). The average age of installed LPTs in the United States is approximately 40 years, with 70% of LPTs being 25 years or older.[69] DOE's Office of Electricity is challenging you to develop innovative business models to stimulate the adoption of flexible LPTs in the electric sector.

Bonus Challenge

DOE's Office of Electricity is challenging you to develop innovative business models to stimulate the adoption of flexible LPTs in the electric sector.

Evaluation Statement

The presentation outlines a clear understanding of LDES technologies and the LDES market space, explores barriers to greater LDES adoption, and proposes an innovative business plan to accelerate LDES deployment for a defined, innovative use case.

Content

Introduction

Securing energy technology supply chains as the energy sector transitions to clean energy is critical to current and future U.S. national security. Earlier this year, DOE laid out the federal government's first-ever comprehensive strategy for securing U.S. energy supply chains.[70] In June 2022, President Biden issued presidential determinations to DOE to utilize the Defense Production Act authority to accelerate domestic manufacturing and deployment of five key energy technologies, including LPTs.

LPTs are custom-designed equipment that entail significant capital expenditures and long lead times due to a complex procurement and manufacturing process. Procurement and manufacturing of LPTs requires prequalification of manufacturers, a competitive bidding process, the purchase of raw materials, and special modes of transportation due to the size and weight of LPTs. Production times can be elongated due to the time required to set up a manufacturing line for a custom design. In

69 Large Power Transformers and the U.S. Electric Grid (energy.gov)

70 Office of Electricity Releases Deep-Dive Supply Chain Assessment of Grid Energy Storage and Electric Grid Components | Department of Energy

some cases, if the manufacturer has difficulty obtaining certain key parts or materials, delivery times can stretch up to 36 months.[71]

DOE's Office of Electricity has supported research and development to develop flexible LPTs that could reduce the need for custom-designed LPTs and reduce manufacturing lead times. The goal of this bonus challenge is to accelerate the manufacture and adoption of flexible LPTs.

Technology Overview

LPTs are a critical component of the electric delivery system, with more than 90 percent of consumed electricity passing through one at some point. The term LPT is broadly used to describe a power transformer with a maximum nameplate rating of 100 megavolt-amperes (MVA) or higher, unless otherwise noted. These components are used to "step up" the voltage at generation facilities for efficient, long-haul transmission of electricity and to "step down" the voltage at distribution substations to levels more readily used by customers. LPTs are also needed at every point in the transmission system where there is a change in voltage.[72]

Due to the significant capital expenditure, long lead time, and unique specifications associated with the procurement and manufacturing of a replacement LPT, there is an opportunity to adopt more flexible and adaptable LPT designs that can facilitate transformer sharing and long-term replacement in the event of catastrophic failures, thereby increasing grid resilience. Additionally, there is an opportunity to integrate enhanced functionality in these new designs to support operation and evolution of the future grid.

Costs

The costs of regular LPTs vary by manufacturer and by size; an LPT can cost between $2 and $7 million and weigh between approximately 100 and 400 tons (or between 200,000 and 800,000 pounds).[73] On the other hand, the cost of a flexible LPT is unclear due to the novelty of the technology. General Electric (GE) recently developed and installed the world's first flexible LPT in partnership with DOE. This flexible LPT is rated at 165 kV and 60/80/100 MVA, and it has three low-voltage ratings (57.5/69/80.5 kV) and an online adjustable impedance of 4.3%–9.2% system.[74] Other flexible LPT designs could further reduce the need for customization, in turn reducing long lead and wait times for production.

Market Opportunity

There is a significant market opportunity for flexible LPTs, as the United States is one of the world's largest markets for power transformers and holds the largest installed base of LPTs—and this installed base is aging. The average age of installed LPTs in the United States is approximately 40 years, with 70% of LPTs being 25 years or older. Although the life expectancy of a power transformer

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[71] Next Generation Transformers – Flexible and Adaptable Designs | netl.doe.gov

[72] An overview of Large Power Transformer - LPT (Characteristics, Costs and Pricing) (electrical-engineering-portal.com)

[73] Strategic Transformer Reserve Report - FINAL.pdf (energy.gov)

[74] GE Research and Prolec GE Power Up World's 1st Large Flexible Transformer to Enhance the Resiliency of America's Grid | GE News

varies depending on how it is used, aging power transformers are subject to an increased risk of failure.

Additionally, the currently challenging LPT supply chain and lead time considerations highlight the opportunity for flexible LPTs that can facilitate transformer sharing and long-term replacement and potentially reduce lead times.

Office of Electricity Bonus Focus: Long-Duration Energy Storage

Statement of Interest

Long-duration energy storage (LDES) is essential to a reliable, resilient, and decarbonized future electricity system. Cheaper and more efficient storage will make it easier to capture and store renewable clean energy for use when energy generation is unavailable or lower than demand. While shorter duration storage is currently being installed to support today's level of renewable energy generation, longer-duration storage is needed to support the affordability, reliability, and resilience of a decarbonized, transformed future electricity system.

Bonus Challenge

DOE's Office of Electricity is challenging you to develop an innovative business plan to propose an LDES technology solution, explain the technology's use case, and address market challenges to enable greater adoption of LDES on the U.S. power system. Innovative energy storage use cases are encouraged.

Evaluation Statement

The presentation outlines a clear understanding of LDES technologies and the LDES market space, explores barriers to greater LDES adoption, and proposes an innovative business plan to accelerate LDES deployment for a defined, innovative use case.

Content

Introduction

Grid-scale energy storage is a critical element driving and supporting the evolution of the electricity system. In the past several years, there has been a significant increase in renewable energy deployed on the U.S. grid as the costs of clean energy technologies have substantially dropped. At the same time, there is a renewed focus on grid reliability and resilience, especially considering the drastic system changes. Grid-scale energy storage intersects these transformations: these technologies support decarbonization by providing load when renewable resources have reduced availability, act as a grid-enhancing technology (GET) by increasing the utilization of transmission, and enhance grid flexibility during peak times or when electric vehicle charging use is high. The importance of energy storage on the power system is growing annually, and projections for energy storage needs in 2035 and 2050 to support decarbonization are significantly above today's levels (some analyses, such as a study performed by the National Renewable Energy Laboratory, project over 200 GWh of grid storage capacity in 2030).

While short-duration storage (primarily lithium-ion batteries providing less than 10 hours) is the predominant configuration currently being installed, longer-duration storage technologies (providing 10+ hours) are needed to support a variety of clean energy and resilience applications as the amount of renewable energy increases and the electricity system continues transforming.

Technology Overview

Lithium-ion batteries make up the majority of grid energy storage for durations of less than 10 hours, as well as the majority of new grid deployments. Pumped storage hydropower (PSH), the vast majority of which dates back to the second half of the 20th century, currently provides most of the longer-duration (10 hours and above) storage, with 43 projects in the United States currently providing 21.9 GW of installed capacity. Lithium-ion batteries are the least expensive alternative at shorter durations and are expected to continue to earn significant market share. Grid storage technologies enable greater penetration of renewables through load-shifting and arbitrage, improve grid reliability, reduce congestion, and increase profitability. They also serve other use cases, such as providing ancillary services like frequency regulation or reserves, and helping better utilize existing transmission and distribution assets, thus deferring investments.

While lithium-ion batteries and PSH dominate new and historical deployments, respectively, there are dozens of promising grid storage technologies, including electrochemical, electromechanical, thermal, and chemical storage. Over the last several decades, DOE has funded or supported dozens of different energy storage technologies for a variety of use cases, including long-duration applications. DOE's Office of Electricity did a deep-dive analysis into 10 energy storage technologies as part of the Storage Innovations 2030 initiative, and also ran a prize competition to explore the landscape of emerging, innovative technologies. There are several dozen storage technologies that may have promise for the grid of today or the future.

Barriers still exist to wider deployment of LDES. These barriers include cost, geographical constraints (for some technologies), technology validation, permitting, manufacturing scale-up, and workforce development.

Costs

In 2021, DOE launched the Long-Duration Storage Shot, which established the target to reduce the cost of grid-scale energy storage by 90%, to $0.05/kWh levelized cost of storage (LCOS), for systems that deliver 10+ hours of duration by 2030. The Long-Duration Storage Shot is part of DOE's Energy Earthshots Initiative, which aims to accelerate breakthroughs of more abundant, affordable, and reliable clean energy solutions within the decade. Achieving the Energy Earthshots will help America tackle the toughest remaining barriers to addressing the climate crisis. The Long-Duration Storage Shot considers all types of technologies—whether electrochemical, mechanical, thermal, chemical carriers, or any combination—that have the potential to meet the necessary duration and cost targets for grid flexibility.

Recent DOE announcements have required that proposed LDES technologies show a clear pathway to the $0.05/kWh LCOS goal.

Market Opportunity

Grid energy storage is poised to grow significantly in the United States. NREL's Storage Futures study projects new storage deployments in the range from 100 to 650 GW of new capacity by 2050, a significant increase from the 23 GW of storage capacity in 2020 (most of which is decades-old PSH). Storage costs are projected to continue to fall, with cost projections described in the Pacific Northwest National Laboratory's (PNNL) Cost and Performance report, and the potential for significant cost reductions through R&D analyzed in the Office of Electricity's Long Duration Storage

Shot Technology Strategy Assessments. LDES represents a major market opportunity given its critical role in decarbonization and plummeting costs; however, technical and market barriers remain.

Additional Resources

- Long Duration Storage Shot: https://www.energy.gov/eere/long-duration-storage-shot
- Storage Innovations 2030: https://www.energy.gov/oe/storage-innovations-2030
- NREL Storage Futures Study: https://www.nrel.gov/analysis/storage-futures.html
- PNNL Cost and Performance Report 2022: https://www.pnnl.gov/sites/default/files/media/file/ESGC%20Cost%20Performance%20Report%202022%20PNNL-33283.pdf
- Grid Energy Storage Supply Chain Deep Dive Assessment (February 2022): https://energy.gov/sites/default/files/2022-02/Energy%20Storage%20Supply%20Chain%20Report%20-%20final.pdf
- Energy Storage Valuation: A Review of Use Cases and Modeling Tools (2022): https://www.energy.gov/sites/default/files/2022-06/MSP_Report_2022June_Final_508_v3.pdf
- Long-Duration Energy Storage Request for Information (May 2022): https://www.energy.gov/oe/articles/long-duration-energy-storage-everyone-everywhere-initiative-notice-intent-and-request

Office of Fossil Energy and Carbon Management Bonus Focus: Carbon Dioxide Removal

Statement of Interest

Deep decarbonization pathways that can be realistically applied in the United States were modeled to keep the global temperature change within a 2°C, 1.5°C, and 1°C rise (Paris Agreement). The results illustrated that, in addition to mitigation strategies such as energy efficiency, renewable electricity production, and process electrification, the capture and storage of carbon dioxide (CO_2) in a manner intended to be permanent (e.g., geological sequestration or long-lived products) will be required to reach net-zero emissions. According to the Intergovernmental Panel on Climate Change, carbon dioxide removal (CDR) will be required to meet the targets described in the Paris Agreement, and CO_2 removal technologies will play a vital role in carbon management.[2] Therefore, 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) with storage, biomass carbon removal and storage (BiCRS), enhanced mineralization, and marine pathways.

Bonus Challenge

DOE's FECM is challenging you to develop innovative business models to increase the adoption of CDR technologies.

Evaluation Statement

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

The proposed business model should include all relevant unit flows for the applicable system and should clearly demonstrate that more CO_2 is removed from the atmosphere than emitted. The business model can be multifaceted to include any disaggregated product system. CDR processes must strive to maximize energy efficiencies and minimize costs.

Content

Introduction

President Biden has set a goal for the United States to achieve a 50%–52% reduction from 2005 levels in economywide net greenhouse gas pollution by 2030.[3] This target builds on progress to date and positions American workers and industries to tackle the climate crisis.[3] 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 economywide by no later than 2050.[3]

In contrast to most CO_2 abatement technologies that reduce emissions from point sources, CDR technologies remove CO_2 from the atmosphere and durably store it in a manner intended to be permanent.[2] Paired with the simultaneous deployment of mitigation measures and other carbon management practices, CDR is a tool to address emissions from the sectors that are hardest to decarbonize (e.g., agriculture and transportation) and eventually, to remove legacy CO_2 emissions from the atmosphere.[4] To meet the goal of achieving net-zero emissions by 2050, FECM funds research, development, demonstration, and deployment of CDR technologies and conducts rigorous techno-economic and life cycle analyses, all while maintaining a deep commitment to environmental justice.

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 using chemicals or some other medium, which can be regenerated for reuse.[2] Atmospheric CO_2 is very dilute (e.g., 415 ppm) and therefore much harder to capture than the CO_2 found in industrial flue gases, as more dilute CO_2 streams require more energy for separation.[2] Comparatively large volumes of air must be handled for each tonne captured, and larger capture equipment is needed, so DAC projects typically cost more than industrial carbon capture and storage (CCS) applications with similar capacities.[2]

BiCRS projects leverage photosynthesis to capture CO_2 from the atmosphere and store it in the form of biomass. This biomass can then be combusted or converted into heat, electricity, hydrogen, or liquid fuels, where the resulting CO_2 emissions are captured and stored in a manner intended to be permanent.[2] Biomass can also be directly converted into marketable, long-lived products (e.g., biochar and bio-based building materials) or bioliquids or bio-oils, which can then be injected in depleted underground oil fields without the need for carbon capture units or further processing steps. Biomass conversion is generally considered to be carbon-neutral, as the amount of CO_2 released is removed from the atmosphere during growth. Implementing carbon removal and storage with biomass conversion is a promising net-negative emissions technology that could ultimately support the 2050 target goal.

Enhanced mineralization processes accelerate 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.[4] CO_2 mineralization reactions can utilize various materials in different settings, and include the in situ CO_2 mineralization of basalts or ultramafic rocks and the ex situ mineralization of alkaline mine tailings or wastes.[4] In situ mineralization involves injecting CO_2-containing fluids into subsurface rocks without first mining or crushing the rocks (e.g., basalts and ultramafic rocks).[4] Another method to store CO_2 through mineralization is by ex situ reaction with crushed material at the surface.[4] 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. Carbon mineralization of asbestos mine tailings has the added benefit of reducing the risks associated with exposed asbestos.[5] Stockpiles of alkaline waste provide a large sink for CO_2 and a potential opportunity to generate side-stream products or address expensive and hazardous wastes. 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 out of the atmosphere and store legacy emissions in durable products like building materials are gaining attention and investment on a global scale.

Recently, several marine CDR pathways have been proposed to improve the ocean's ability to remove CO_2 from the atmosphere. Many approaches involve increasing the ocean's alkalinity in response to ocean acidification.[6] For example, some approaches involve adding alkaline substances to oceans to convert inorganic CO_2 into carbonates and bicarbonates, thereby increasing the pH. Others involve an electrodialysis process that aims to separate CO_2 from ocean water in the form of a pure stream for subsequent durable storage. Sequestering organic matter deep in the ocean where it is biologically inaccessible (e.g., kelp farming and sinking or artificial fertilization of phytoplankton) can also allow for durable storage of biomass. Protecting and restoring blue carbon ecosystems can also boost the storage of organic carbon in marine soils.

Market Opportunity

Around half of the anticipated emissions reductions required to reach net-zero emissions by 2050 will come from technologies that are not yet commercially deployed, and these new technologies will become increasingly important after 2030.[7] CDR technologies, such as DAC and BiCRS, which help offset residual emissions, also need to scale up significantly, giving rise to negative emissions.[7] A roadmap to net-zero emissions by 2050 showed that for the G7 members (Canada, France, Germany, Italy, Japan, the United Kingdom, the United States), CDR from BiCRS and DAC with storage offset residual emissions of around 1.9 gigatonnes of CO_2, mainly from the transport and industry sectors.[7] Therefore, it is apparent that CDR technologies have an essential role to play 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.[2] However, in general, the market opportunity can be determined via a complete analysis of economic viability and environmental impacts, through techno-economic analysis and life cycle analysis, respectively. It is imperative to perform the life cycle analysis on a cradle-to-grave basis when analyzing the environmental impacts of CDR technologies.

Resources

- https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020AV000284
- Global CCS Institute, 2021. The Global Status of CCS: 2021. Australia.
- 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/
- 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
- https://www.usgs.gov/news/featured-story/making-minerals-how-growing-rocks-can-help-reduce-carbon-emissions
- Ocean Carbon Dioxide Removal (CDR) - ClimateWorks Foundation
- Achieving net-zero electricity sectors in G7 members. International Energy Agency. October 2021.

Additional Resources

- Carbon Utilization Program | netl.doe.gov
- NETL CO_2U LCA TRAINING RESOURCES | netl.doe.gov
- Conference Proceedings | netl.doe.gov

Office of Manufacturing and Energy Supply Chains: Smart Manufacturing for Small- and Medium-Sized Manufacturers

Statement of Interest

Established in 2022 as a new office under the Office of the Under Secretary for Infrastructure, the Office of Manufacturing and Energy Supply Chains (MESC) serves as the front line of clean energy deployment, accelerating America's transition to a resilient, equitable energy future through $20 billion of direct investments in manufacturing capacity and workforce development. MESC develops and provides the analytical tools that help inform programs and investments across DOE and the U.S. government as a whole.

The mission of MESC is to strengthen and scale America's clean energy supply chains, particularly through engagement with small- and medium-sized manufacturers (SMMs), through the following:

- Transformative manufacturing capacity investments
- Targeted investments in the energy workforce of the future
- Cutting-edge energy supply chain vulnerability and innovation analysis.

MESC intends to eliminate vulnerabilities in U.S. clean energy supply chains while driving social, economic, and environmental impact through our programs and awards.

Bonus Challenge

MESC is challenging you to develop innovative and practical business models for deploying smart manufacturing solutions at SMMs—recognizing the need for retrofit projects that accommodate the inherent implementation challenges of these solutions, including uncertain payback periods and financing obstacles.

Evaluation Statement

The entry emphasizes a clear understanding of, and plans to address, the immense opportunities and challenges associated with smart manufacturing at SMMs.

Content

Introduction

The Clean Energy Smart Manufacturing Innovation Institute, or CESMII, defines smart manufacturing as "the information-driven, event-driven, efficient, and collaborative orchestration of business, physical, and digital processes within plants, factories, and across the entire value chain."

Smart manufacturing discussions often involve more automated, often robotic, and centrally monitored operations. While these are clearly game-shifting technologies, smart manufacturing is often most suited to products with complicated geometries, high weight-to-performance requirements (Ngo 2018), or customization needs (Meier 2018). Most of these opportunities will occur when manufacturing capacity is built from the ground up rather than during a retrofit.

That being said, manufacturers with operating plants will need to participate in the smart manufacturing paradigm shift. Deployment of smart manufacturing within this context will be different from previous advances in manufacturing efficiency in several ways. For the most part, retrofit smart projects are highly varied and calculating their savings/benefits is very challenging.

Implementation also requires considerable thought. In the past, some vendors marketed computerized management systems that did not yet generate a net value, which has led to an understandable level of caution among manufacturers in adopting this new set of smart technologies. Without a set of projects that resemble “low hanging fruit,” manufacturers often aren’t sure whether or where to start.

Retrofit technologies provide a pathway to start applying smart manufacturing methods for those SMMs that can quickly change process designs and schedules to meet client needs. Additionally, their small size makes them excellent laboratories for studying how to implement a technical assistance program focused on improving in energy and productivity performance through industrial analytics.

Technology Overview

Much of the interest in smart projects revolves around making them work with limited risk to plant operations. Therefore, projects addressing ancillary systems as opposed to the primary manufacturing line are preferred. There will be cases where a focus on the main product line is desired, but we are looking for easy and repeatable solutions. As ideas are developed, it is necessary to categorize recommendations in several ways—primarily the complexity of the communications, the operations, and the implementation potential.

Smart manufacturing is about communication and information. Many smart projects will involve increasing communication and providing information to either machines or management. Table 13 summarizes the three categories of increased communication that projects could consider.

Table 13. Communication Categories

Category	Description
Direct machine-to-machine communication—essentially, feedback loops without operator involvement	• Feedback without internet services • Feedback with internet services
Feedback requiring management involvement (machines talking to people)	• Alarms • Trending opportunities
Management-initiated feedback (people talking to machines)	• Stepwise improvements • Temporary metering

Alarms are a major source of smart opportunities, as they involve machine interpretation of data, with communication occurring only when necessary. These are powerful tools for busy managers, and commonly involve temperatures or pressures where limits are set to protect equipment, but no direct information is transmitted. An easy project would involve linking a sensor to the cloud so that when limits are exceeded, the cloud would email the plant manager. These tools can have very low energy draws because the sensor only needs to communicate with the cloud when something is amiss.

Trending and stepwise approaches convey trends and incremental changes in the data, which managers can then use to make adjustments. For example, management might look for the low pressure reached by a compressor system during an operation. As leaks in the system or compressor problems develop, this value will slowly decrease.

Temporary metering is a strategy in which implementation costs are the concern. Consider a facility with many buildings. Equipping each with a suite of sensors could be a deal-killer, and potentially unnecessary. A single package of sensors with communication could be used for a period of time in each building and would yield most of what would be learned from individual sensors.

Another basic level of categorization will be which improvement to the current control system is recommended. Sometimes analog solutions (such as proportional-integral-derivative, or PID, controllers) will yield a significant difference and are included in Table 14 as level zero.

Table 14. Classification of Smart Projects

Category	Type of Project	Comment	Simple Example
Level Zero	Adding a control system without communication	Valuable, but not new	Install a PID controller to address overfill, instead of an existing on/off system
Level One	Control system exists	Project adds communication of control system status (includes sensor)	Deploy an automated “free cooling loop” on a chiller system—utilizing the temperature of the cooling tower sump to trigger the loop
Level Two	Control system is added or modified	Project adds communication of control system status	Add a pressure control system on a bag house and send information to operations via the cloud
Level Three	Control system includes nonlocal information in decision-making	Internet or cloud involved	Begin intelligent use of ice storage systems (using weather predictions to decide best melting strategies)

The complexity of implementation depends on how much goes into the actual implementation of a project— from, say, a simple one-axis vibration sensor magnetically coupled to a motor to “computers on a chip" assembled and designed for a single purpose. Potential project ideas can be distributed into the groups in Table 15.

Table 15. Implementation Complexity

Category	Description
"Plug and play"	Sensor and interface are combined and installed as is. Very simple installation.
"Sensor deployment"	Sensor is separate from communication. Input/Output box handles sensor input and cloud communications.
"Custom with coding"	True one-of-a-kind applications. Low cost (Raspberry Pi) but requires both electrical and computing skill sets.

Market Opportunity

Current operations among SMMs present numerous opportunities in retrofit smart manufacturing. The path forward will change over time as the number of successful projects grows and a more robust classification system can be developed.

Additional Resources

- Ngo, T.D., A. Kashani, G. Imbalzano, K.T. Nguyen, and D. Hui. 2018. "Additive manufacturing (3D printing): a review of materials, methods, applications and challenges." *Compos B Eng* 143: 172–196.

- Meier, M., Kim Hua Tan, Ming K. Lim, Leanne Chung. 2018. "Unlocking innovation in the sport industry through additive manufacturing." *Business Process Management Journal*. https://doi.org/10.1108/BPMJ-10-2017-0285.

Office of Nuclear Energy Bonus Focus: Accelerated Development and Deployment

Statement of Interest

The mission of DOE's Office of Nuclear Energy (NE) 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, help realize the potential of advanced technology, and leverage the unique role of the government in spurring innovation:

1. Enable continued operation of existing U.S. nuclear reactors.
2. Enable deployment of advanced nuclear reactors.
3. Develop advanced nuclear fuel cycles and spent nuclear fuel management options.

There is enormous potential to expand into new markets and applications for nuclear energy, from the existing fleet on the nation's grid to advanced reactors and fuel cycle technologies.

Bonus Challenge

NE is challenging you to develop innovative business models to accelerate the development and deployment of advanced technologies supporting advanced nuclear reactors and existing fleet capabilities in the United States.

Evaluation Statement

The entry demonstrates an understanding of the technology and the 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 advanced capabilities that span innovation from materials development through system design and construction. NE investments offer the promise of dramatically improved performance to meet U.S. energy 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 meet 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 nuclear energy challenges.

Technology Overview

NE supports R&D in the following key 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 manage and dispose of the nation's commercial used nuclear fuel and 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 2050, strategies and technologies for 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 involved in 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 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 help meet 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. 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 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 exist a number of market opportunities that broadly fall within the categories of (1) enabling continued operation of existing U.S. nuclear reactors, which includes activities designed to address technical, cost, safety, and security issues associated with the existing commercial light water reactor fleet, (2) enabling deployment of advanced nuclear reactors, and (3) developing advanced nuclear fuel cycles and spent nuclear fuel management options.

Additional Resources

- DOE Office of Nuclear Energy
  https://www.energy.gov/ne/office-nuclear-energy

- History of Nuclear Energy
  https://www.energy.gov/ne/about-us/history
- Fuel Cycle Technologies
  https://www.energy.gov/ne/initiatives/fuel-cycle-technologies
- Nuclear Energy Enabling Technologies
  https://www.energy.gov/ne/nuclear-energy-enabling-technologies-neet
- Nuclear Facility Operations
  https://www.energy.gov/ne/nuclear-facility-operations/
- Nuclear Energy University Program
  https://www.energy.gov/ne/nuclear-energy-university-program
- Gateway for Accelerated Innovation in Nuclear (GAIN)
  https://www.energy.gov/ne/initiatives/gateway-accelerated-innovation-nuclear-gain
- Office of Nuclear Energy Funding Opportunities
  https://www.energy.gov/ne/funding-opportunities
- Nuclear Energy Institute
  https://www.nei.org/home
- Nuclear Innovation: Clean Energy Future
  https://www.energy.gov/ne/nuclear-innovation-clean-energy-future
- Science, Technology, Engineering, and Math (STEM) Resources
  https://www.energy.gov/ne/stem-resources
- Document Library
  https://www.energy.gov/ne/listings/document-library
- Small Modular Reactor Technologies
  https://www.energy.gov/ne/advanced-small-modular-reactors-smrs
- Light Water Reactor Technologies
  https://www.energy.gov/ne/nuclear-reactor-technologies/light-water-reactor-sustainability-lwrs-program
- Advanced Reactor Technologies
  https://www.energy.gov/ne/advanced-reactor-technologies
- Versatile Test Reactor
  https://www.energy.gov/ne/versatile-test-reactor
- Space Power Systems
  https://www.energy.gov/ne/nuclear-reactor-technologies/space-power-systems

Office of Technology Transitions Bonus Focus: National Lab IP Licensing

Statement of Interest

The mission of the Office of Technology Transitions (OTT) is to expand the public impact of the department's research, development, demonstration, and deployment (RDD&D) portfolio to advance the economic, energy, and national security interests of the nation. OTT is the front door to DOE's products, facilities, and expertise. The office integrates "market pull" into its planning to ensure the greatest return on investment from DOE's RDD&D activities to the taxpayer.[75]

Hosting one of the world's largest science research enterprises, DOE helps power and secure America's future through technological advancement and strategic support. DOE's RDD&D capabilities, and the innovations they enable, help maintain the United States' role as the global leader in science and technology. In particular, technology transfer supports the maturation and deployment of DOE-powered innovation, providing ongoing economic, security, and environmental benefits for all Americans.[76]

In 2015, the Secretary of Energy authorized the formation of OTT to develop and oversee the delivery of DOE's strategic vision and goals for technology commercialization and engagement with business and industry across the United States. OTT's statutory authority is derived from the Bayh-Dole Act of 1980, the Stevenson-Wydler Technology Innovation Act of 1980, the Energy Policy Act of 2005, and the Energy Act of 2020. OTT's mission is to expand the commercial impact and public benefit of DOE's RDD&D portfolio to advance the economic, energy, and national security interests of the nation.[77]

Bonus Challenge

OTT is challenging you to develop innovative business models to help accelerate the commercialization of technologies available on the Lab Partnering Service.

Evaluation Statement

The entry demonstrates a clear understanding of the technology and market potential of a technology listed on the OTT's Lab Partnering Service and presents an innovative business model to significantly increase its adoption.

Content

Introduction

OTT serves as the central hub for technology transfer activities across DOE's extensive R&D enterprise. At OTT, we work to ensure that groundbreaking scientific discoveries achieve their

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[75] https://www.energy.gov/technologytransitions/mission-0
[76] Ibid.
[77] Ibid.

maximum public return and impact, advancing the economic, energy, and national security interests of the United States. That means streamlining access to our user facilities at our 17 national labs and sites, our world-class scientific researchers, and our sprawling portfolio of intellectual property—fostering strong internal and external partnerships that guide innovations from the lab toward the marketplace.[78]

Technology transfer is a complex and dynamic process, and OTT is here to help you connect with DOE-powered innovation to advance discoveries and commercialize transformative, impactful technologies.[79] One of the best ways to expand DOE's commercial impact is raising awareness among investors and industry about the capabilities and expertise housed at the agency's 17 national laboratories and facilities.[80]

Lab Partnering Service Tool

OTT's Lab Partnering Service (LPS) offers unprecedented access to the world's most advanced scientific facilities and researchers across DOE's national lab complex. LPS provides investors—and other parties looking to advance energy innovation—a single online platform to connect with leading DOE national laboratory technical experts to quickly answer innovation questions, as well as discover opportunities for building partnerships. Visitors can easily search hundreds of technologies, patents, experts, facilities, and success stories tailored to their individual needs. Applicants can search for technologies in LPS with the "EnergyTech University Prize" tag to find technologies identified for this competition.[81]

Resources

- Lab Partnering Service
  https://labpartnering.org/ (search for "EnergyTech University Prize" in the "Discover…" search bar)
- Office of Technology Transitions
  https://www.energy.gov/technologytransitions/office-technology-transitions

Success Stories

- 2022 first-place team leveraged a technology from Ames National Laboratory: Mechanochemical Recover of Co, Li, and Other Essential Components from Spent Lithium-Ion Batteries.
- Lab Partnering Service Success Stories:
  https://labpartnering.org/search?typ%5B%5D=success_stories

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78 https://www.energy.gov/technologytransitions/office-technology-transitions
79 Ibid.
80 https://www.energy.gov/technologytransitions/lab-partnering-service
81 Ibid.

Solar Energy Technologies Office 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 novel solar technology of your choice that tackles emerging challenges in the solar industry and aims to improve the performance, affordability, reliability, and value of solar energy in the United States. The business model goal should be to increase the adoption of new solar technologies and maximize the performance and/or reduce the costs associated with the 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 the 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 economywide by 2050.[82] Solar energy, being the fastest-growing electricity source,[83] is expected to be key part of the U.S. strategy to achieve these goals. Solar generation satisfied about 3% of total U.S. electricity demand in 2020, and it is projected to serve 37%–42% of electricity demand by 2035.[84] Such substantial growth needs to be supported by technology innovation that addresses 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

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[82] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

[83] https://www.c2es.org/content/renewable-energy/

[84] https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf

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.[85]

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%–22%.[86] However, efficiencies keep improving, and newer monocrystalline solar cell have reached efficiencies over 26%.[87] Photovoltaic installations exist as 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 medium, which can then be used to produce electricity, drive a variety of industrial applications requiring process heat, or be stored for later use. It is used primarily in very large power plants.[88]

Costs

Solar system costs comprise 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)[89] 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.[90]

Over the past decade, solar energy has achieved significant cost reductions resulting in very competitive LCOE.[91] Although the cost may vary drastically based on the amount of sunlight and type of solar panels installed, currently, the residential solar energy cost is about $0.08–$0.10/kWh on average, while the commercial or utility-scale solar power cost is about $0.06–$0.08/kWh.[92] DOE is targeting an LCOE for solar of $0.02–$0.05/kWh by 2030.[93]

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[85] https://www.energy.gov/eere/solar/how-does-solar-work
[86] https://www.energy.gov/eere/solar/crystalline-silicon-photovoltaics-research
[87] https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf
[88] https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics
[89] https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf
[90] https://en.wikipedia.org/wiki/Levelized_cost_of_energy#:~:text=The%20levelized%20cost%20of%20energy,generation%20on%20a%20consistent%20basis.
[91] https://www.energy.gov/eere/solar/goals-solar-energy-technologies-office
[92] https://homeguide.com/costs/solar-panel-cost
[93] Ibid.

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 3–10 kW_{DC} in size, while commercial and industrial rooftop PV installations are more commonly between 30 kW_{DC} and 1 MW_{DC}. Such systems can be grid-connected systems or isolated, stand-alone systems and are often coupled with energy storage systems (ESS) or electric vehicle (EV) charging systems. SETO is interested in technologies that can reduce installation costs of 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. This also includes the development and operation of virtual power plants (VPPs), which are a connected aggregation of DER technologies operated in a coordinated way. VPPs offer deeper integration of renewables and demand flexibility, which in turn offers cleaner and more affordable power[94] and methodologies, algorithms, and software solutions for the control, operation, and grid integration of DERs and VPPs.

Photovoltaic Cell Technologies and Materials

About 95% of the solar panels on the market today use either monocrystalline silicon or polycrystalline silicon as the semiconductor.[95] 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[96]:

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

Vehicle-Integrated Photovoltaics (VIPV)

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94 https://www.energy.gov/lpo/virtual-power-plants
95 https://www.energy.gov/eere/solar/articles/pv-cells-101-primer-solar-photovoltaic-cell
96 https://www.energy.gov/eere/solar/articles/pv-cells-101-part-2-solar-photovoltaic-cell-research-directions
97 https://www.nrel.gov/docs/fy00osti/25272.pdf

The field of vehicle-integrated photovoltaics (VIPV) designates the mechanical, electrical and design-technical integration of photovoltaic modules into vehicles.[98] The photovoltaic modules integrate seamlessly into the vehicle exterior and electric system architecture to supply power to onboard electric loads or batteries. VIPV modules serve dual functionality by generating electric energy while replacing other structural parts of the vehicle, like the roof, the hood, the doors, the windows, the windshield, the sunroof, or other glass components. In simpler cases, referred to as vehicle-added or attached PV (VAPV), more traditional individual PV modules are attached to the existing vehicle structure serving only the energy generation role.

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 allows agricultural activities to continue, with agricultural production taking place underneath solar panels, around solar panels, or both. Agrivoltaic systems enable farmers, ranchers, and other agricultural enterprises to gain value from solar technologies while keeping land available for agricultural purposes.[99] Solar panels can be used in both open-field agriculture, in the form of solar arrays above crops or arrays with spacing in between 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.[100] 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 bodies of water, like freshwater reservoirs, wastewater ponds, or hydropower reservoirs.

Power Electronics

Power electronic (PE) devices are used to extract electric energy from solar panels and make it available for use by other devices. Inverters are used to convert the direct current (DC) electricity generated by PV modules into alternating current (AC) electricity, which is used for local transmission of electricity, as well as most appliances in our homes. DC/DC converters, on the other hand, 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 improve the performance of solar systems, and also, in cases that include more advanced control schemes, allow them to provide operational services to the grid they are connected to, just like traditional power generators.[101, 102] Inverters and other PE converters typically use silicon-

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[98] https://www.ise.fraunhofer.de/en/key-topics/integrated-photovoltaics/vehicle-integrated-photovoltaics-vipv.html
[99] https://www.energy.gov/eere/solar/seto-2020-solar-and-agriculture
[100] https://www.nrel.gov/state-local-tribal/blog/posts/floating-solar-photovoltaics-could-make-a-big-splash-in-the-usa.html
[101] https://www.energy.gov/eere/solar/solar-photovoltaic-system-design-basics
[102] https://www.energy.gov/eere/solar/solar-integration-inverters-and-grid-services-basics

based power electronics. Recently, new wide-bandgap semiconductor materials like silicon carbide (SiC) and gallium nitride (GaN) have been used in PE devices, demonstrating significant benefits and operating advantages, like smaller device sizes, lower weights, and higher efficiencies.[103] In addition, new ultrawide-bandgap semiconductors, like gallium oxide (Ga_2O_3), could become even more promising in the near future.

Concentrating Solar Power

CSP technologies use mirrors to reflect and concentrate sunlight onto a receiver. The energy from the concentrated sunlight heats a high-temperature medium in the receiver. This heat can be used to power a turbine to generate electricity, but the same basic technologies can also be used to deliver heat to a variety of industrial applications, like water desalination, enhanced oil recovery, food processing, chemical production, and mineral processing. CSP systems are generally used for utility-scale projects, but smaller CSP systems can also be located directly where power is needed for specific industrial applications.[104,105]

Software Solutions

Software systems and software-enabled business models that aim at improving the performance, reliability, and affordability of solar systems by automating processes and procedures during the design, installation, and operation of such systems. Software solutions could involve, but are not limited to, system modeling, simulation, design, installation support or automation, asset performance monitoring and management, plant control and operation optimization, etc.

Additional Resources

General

- DOE – Solar Energy Technologies Office
  https://www.energy.gov/eere/solar/solar-energy-technologies-office

Solar Technologies Background

- DOE/SETO – How Does Solar Work?
  https://www.energy.gov/eere/solar/how-does-solar-work
- DOE/SETO – Solar Energy Success Stories
  https://www.energy.gov/eere/solar/solar-energy-success-stories
- DOE/SETO – Solar Futures Study
  https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf

Photovoltaic Technology Background

- DOE/SETO – Photovoltaics
  https://www.energy.gov/eere/solar/photovoltaics
  https://www.energy.gov/eere/solar/solar-photovoltaic-technology-basics
- NREL – Solar Photovoltaic Technology Basics
  https://www.nrel.gov/research/re-photovoltaics.html

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103 https://www.energy.gov/eere/solar/silicon-carbide-solar-energy
104 https://www.energy.gov/eere/solar/concentrating-solar-thermal-power
105 https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics

- U.S. Energy Information Administration (EIA) – Solar Explained
  https://www.eia.gov/energyexplained/solar/photovoltaics-and-electricity.php
- Solar Energy Industries Association (SEIA) – Photovoltaics
  https://www.seia.org/initiatives/photovoltaics
- Solar Energy Development Programmatic EIS (SOLAREIS) – Solar Photovoltaic Technologies
  https://solareis.anl.gov/guide/solar/pv/index.cfm

Next-Generation Power Electronics for Inverters/Converters

- DOE/SETO – Solar Power Electronic Devices
  https://www.energy.gov/eere/solar/solar-power-electronic-devices
  https://www.energy.gov/eere/solar/advanced-power-electronics-design-solar-applications-power-electronics
  https://www.energy.gov/eere/solar/silicon-carbide-solar-energy

Perovskite Solar Cells

- DOE/SETO – Perovskite Solar Cells
  https://www.energy.gov/eere/solar/perovskite-solar-cells
- NREL – Perovskite Solar Cells
  https://www.nrel.gov/pv/perovskite-solar-cells.html

Building Integrated Photovoltaics (BIPV)

- SEIA – Building Integrated Photovoltaics
  https://www.seia.org/initiatives/building-integrated-photovoltaics
- NREL – Building Integrated Photovoltaic Designs
  https://www.nrel.gov/docs/fy00osti/25272.pdf
- Whole Building Design Guide (WBDG) – Building Integrated Photovoltaics
  https://www.wbdg.org/resources/building-integrated-photovoltaics-bipv
- DOE/SETO – Building Integrated Photovoltaics (BIPV)
  https://www.energy.gov/eere/solar/request-information-building-integrated-photovoltaics
- Architectural Solar Association (ASA)
  https://www.archsolar.org/

Vehicle-Integrated Photovoltaics (VIPV)

- DOE/SETO – Vehicle Integrated Photovoltaics (VIPV)
  https://www.energy.gov/eere/solar/request-information-challenges-and-opportunities-vehicle-photovoltaics
- Fraunhofer ISE – Vehicle-Integrated Photovoltaics
  https://www.ise.fraunhofer.de/en/key-topics/integrated-photovoltaics/vehicle-integrated-photovoltaics-vipv.html
- European PV Technology and Innovation Platform (ETIP PV). VIPV Position Paper – Vehicle-integrated Photovoltaics as a core source for electricity in road transport
  https://etip-pv.eu/publications/etip-pv-publications/download/vehicle-integrated-photovoltaics-vipv-as-a-core-so

Agrivoltaics

- National Center for Appropriate Technology (NCAT) – AgriSolar Clearinghouse

https://www.agrisolarclearinghouse.org/
- University of Arizona – What is Agrivoltaics?
  https://research.arizona.edu/stories/what-is-agrivoltaics
- NREL – Benefits of Agrivoltaics Across the Food-Energy-Water Nexus
  https://www.nrel.gov/news/program/2019/benefits-of-agrivoltaics-across-the-food-energy-water-nexus.html

Floatovoltaics

- NREL – Floating Solar Photovoltaics Could Make a Big Splash in the USA
  https://www.nrel.gov/state-local-tribal/blog/posts/floating-solar-photovoltaics-could-make-a-big-splash-in-the-usa.html
- NREL – Enabling Floating Solar Photovoltaic (FPV) Deployment
  https://www.nrel.gov/docs/fy21osti/76867.pdf

Concentrating Solar-Thermal Power

- DOE/SETO - Concentrating Solar-Thermal Power
  https://www.energy.gov/eere/solar/concentrating-solar-thermal-power
- DOE/SETO - Concentrating Solar-Thermal Power Basics
  https://www.energy.gov/eere/solar/concentrating-solar-thermal-power-basics

Relevant Lab Partnering Service Technologies

1. Improved Method for Measuring Solar Irradiance (Sandia National Laboratories) – https://doelps.org/HYOP2z
   Inexpensive, efficient, and accurate method of measuring the irradiance from solar reflections using a digital camera.
2. Alternating Current Photovoltaic Building Block (Sandia) – https://doelps.org/QW3bv7
   Fully integrated and self-containing AC PV building block device and method that allows PV applications to become true plug-and-play devices.
3. Enhanced Thin Film Organic Photovoltaic Devices (Brookhaven National Laboratory) – https://doelps.org/eVGpwF
   A novel structure design for thin-film 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) – https://doelps.org/zkJkv9
   Heat transfer fluid 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 Success Stories

Photovoltaic Cells and Panels

1. Sandia-Led Center To Advance Understanding of New Solar Panel Technology (Sandia – 2021)
   https://www.labpartnering.org/stories/651979fe-3e7d-49a9-b72d-eebe8dcdc0a1
   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)

https://www.labpartnering.org/stories/f1ce61a2-8292-4d97-b6c5-2d88243486d2
Single-axis tracking design for commercial rooftop solar.

3. Sandia-Developed Solar Cell Technology Reaches Space (Sandia – 2021)
   https://www.labpartnering.org/stories/68d77320-c444-4ec4-b3a4-f47affdd122b
   Solar cell technology of highly interconnected photovoltaic cells ("solar glitter") that reduces cost and increases efficiency.
4. Miniature Flexible Solar Panels (Sandia – 2020)
   https://www.labpartnering.org/stories/424e1775-62bc-4082-b1f2-3bb9211a0308
   Microsystems-enabled photovoltaics (MEPV) technology ("solar glitter") with improved flexibility and ability to conform to shapes.
5. SunPower and Sandia Partnership Leads to Demonstration of Innovative New Module Technology (Sandia – 2020)
   https://www.labpartnering.org/stories/2c30dda0-53ad-4b31-9873-bfbec180bebc
   Experimental photovoltaic PV system at the New Mexico Regional Test Center (RTC), co-located with Sandia's Photovoltaic Systems Evaluation Laboratory (PSEL).
6. Crystal Solar and NREL Team Up To Cut Costs (NREL – 2014)
   https://www.labpartnering.org/stories/4c090bdd-a1e4-45e9-bd4c-3901b1a4acc4
   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.
7. Award-Winning Etching Process Cuts Solar Cell Costs (NREL – 2013)
   https://www.labpartnering.org/stories/3d7e261a-9cd0-4c32-ab83-1e32ca4af238
   Award-winning etching process allowing solar cells to absorb more than 98% of incident sunlight and reducing solar cell costs.

Concentrating Solar Power

1. Sandia's Expertise Puts a Round 4 American-Made Solar Prize Winner's Innovation to the Test (Sandia – 2021)
   https://www.labpartnering.org/stories/c17a15f8-9cdd-4f12-9abc-afdd1bf30f5c
   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.
2. Testing Heat Exchangers Helps Move Solar Plans Forward (Sandia – 2021)
   https://www.labpartnering.org/stories/2d7fa4fb-0077-4a8e-a4ef-2ef83a9e2b2a
   Evaluation of heat exchanger performance for CSP projects.
3. STARS Harnessing the Sun To Make Gases and Chemicals (Pacific Northwest National Laboratory – 2019)
   https://www.labpartnering.org/stories/4445a9d8-3be6-4955-aadb-2672b81e37dd
   Technology that captures sunlight in a parabolic dish and concentrates it to drive a chemical reaction producing chemical energy with 70% efficiency.
4. Falling Particle Receiver for Concentrated Solar Energy (Sandia – 2018)
   https://www.labpartnering.org/stories/ec7e7c03-1c47-490e-b30d-9a14a357103f
   A falling particle receiver for CSP systems 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

1. NREL SolarCity and the Hawaiian Electric Companies (NREL – 2018)
   https://www.labpartnering.org/stories/ab659062-9685-4d6f-be61-12cd928ed4c6
   Addressing the safety, reliability, and stability challenges of interconnecting high penetrations of distributed PV with the electric power system.
2. Hawaiian Electric Advances Solar Inverters (NREL – 2016)
   https://www.labpartnering.org/stories/5f0e6edf-89a3-44b8-a63c-5e43730debf9
   Testing and performance demonstration of solar inverter functionality.
3. NREL + SOLECTRIA (NREL – 2015)
   https://www.labpartnering.org/stories/f30ce8ab-aab4-4742-bac5-e8ed311fc6d9
   Development of 500- and 750-kilowatt PV inverters with advanced features that can support the electric grid.
4. NREL GOOGLE (NREL – 2015)
   https://www.labpartnering.org/stories/3f312a2b-10f3-4963-a7e5-e57f7e771723
   Little Box Challenge: an open competition challenging engineers to build smaller power inverters for use in PV power systems.

Hybrid PV + Storage Systems

1. Sandia App Assesses Value of Energy Storage for Businesses Utilities (Sandia – 2021)
   https://www.labpartnering.org/stories/58dbdabe-c0b0-4fb8-a11a-088bee9b2c68
   Software (Quest) to evaluate different energy storage scenarios and model the potential of new solutions.
2. Stafford Hill Microgrid (ORNL – 2018)
   https://www.labpartnering.org/stories/a9d40ab4-bad9-4dc9-9268-cd675d92be76
   A 4MW/3.4-MWh battery system coupled with over 2 MW of solar PV located in western Vermont.
3. REopt Lite Tool To Optimize PV and Battery System Sizes (NREL – 2018)
   https://www.labpartnering.org/stories/4194b840-d882-4805-8ee3-48efa41d5898
   Free online tool to help with siting, sizing, and financially evaluating PV and battery storage projects.

Solar System Performance Evaluation

1. Sandia Uncovers Hidden Factors That Affect Solar Farms During Severe Weather (Sandia – 2021)
   https://www.labpartnering.org/stories/0d99c201-87e1-42e1-a8bd-ceac058e015b
   Advanced machine learning to study the impacts of severe weather on U.S. solar farms.
2. Rooftop Solar Panels Get Boost From Sandia Tool That Previews a Year on Grid in Minutes (Sandia – 2019)
   https://www.labpartnering.org/stories/9558995c-edbf-4996-a092-0f6c813972cd
   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.
3. MOU Launches Collaboration To Study Photovoltaic Performance and Reliability Worldwide (Sandia – 2019)
   https://www.labpartnering.org/stories/d5565f18-0fe4-49d7-bd72-c8b98d5b346f
   Platform for studying photovoltaic performance and reliability in multiple diverse environments and climates.
4. SGHAT Software (Sandia – 2018)

https://www.labpartnering.org/stories/d6539eba-66f6-493b-9838-87a4ebcb0814
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

1. Materials Developed at Sandia Help Extinguish Solar Panel Fires Before They Ignite (Sandia – 2020)
   https://www.labpartnering.org/stories/53462aa9-9ec6-426d-b5ac-faebbd6307fc
   Development of electrical in-line connectors that automatically predict and prevent PV arc-faults before they can ignite electrical fires.
2. Ensuring Cybersecurity in Solar Energy Systems (Sandia – 2020)
   https://www.labpartnering.org/stories/65ec6f76-dca0-45a3-9f57-1557594c8240
   Creation of cybersecurity standards and best practices for distributed energy resources.

Water Power Technologies Office Bonus Focus: Powering the Blue Economy

Statement of Interest

America has vast marine energy and hydropower resources, and there remains enormous potential to expand into new markets and applications and to increase generation and flexibility across the nation's sizable hydropower and pumped storage fleet. DOE's Water Power Technologies Office (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. (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.)

WPTO also seeks to support equitable and just marine energy and hydropower industries and blue economy, with diversity at all levels of the industry and workforce, providing benefits to all.

Bonus Challenge

WPTO is challenging you to develop an innovative business model for a novel hydropower or marine technology of your choice that tackles emerging challenges in the water power industry and aims to improve the performance, affordability, reliability, and value of hydropower or marine energy in the United States.

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. The team demonstrates a commitment to diversity, equity, inclusion, and justice.

Content

Introduction

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

Water power also has important benefits across multiple infrastructure sectors and 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. It 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.[106] Hydropower technologies generate power by using the elevation difference, created by a dam or diversion structure, of water flowing in one side and out the other. Hydropower offers flexibility in both the short and long term to support and complement variable renewable energy; pumped storage hydropower (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 complements other renewable energy sources.

Marine Energy

Marine energy, also known as marine renewable energy or marine and hydrokinetic energy, 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, 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 a near-term solution for distributed energy for isolated and islanded communities.

Market Opportunity

There is enormous potential to expand into new markets and applications for both marine and hydropower and to extract more energy from the existing assets on the nation's grid. Areas of opportunity include advancing existing hydropower facilities and non-powered dams to 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 new, innovative projects. Hydropower capacity has increased by a net 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 powering of non-powered dams.[107] At the end of 2019, an additional 1,490 MW from 217 projects were in the U.S. development pipeline, 93% of which was slated to come from powering non-powered dams and expanding existing facilities.[108] PSH represents a particular area of opportunity, as the vast majority of energy storage capacity in the

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106 https://www.eia.gov/energyexplained/hydropower/

107 https://www.energy.gov/eere/water/downloads/us-hydropower-market-report
108 Ibid.

United States is PSH, and PSH is the preferred least-cost technology option for energy storage between 4 and 16 hours in duration.[109] Hydropower and its facilities also present an opportunity to capitalize on several non-powered benefits.[110]

Because marine energy resources are sizable, predictable, reliable, geographically diverse, and can be developed in an environmentally responsible manner, marine energy represents a significant and emerging market across the entire United States, and particularly in the blue economy. DOE's Powering the Blue Economy initiative seeks to understand the power requirements of coastal and maritime markets and to 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 experiments, and security activities (such as ocean observation and navigation or marine aquaculture) and (2) improving the resiliency of coastal communities by helping meet their energy and water needs (for example, through desalination or powering microgrids in remote areas).[111]

Additional Resources

- DOE Water Power Technologies Office
  https://www.energy.gov/eere/water/water-power-technologies-office
- Water Power Technologies Office 2020–2021 Accomplishments Report
  https://www.energy.gov/eere/water/water-power-technologies-office-2020-2021-accomplishments-report
- Energy I-Corps Resources: Tools and Training for Entrepreneurs
  https://www.osti.gov/biblio/1867238-review-technology-innovations-pumped-storage-hydropower
- Hydropower Explained
  https://www.eia.gov/energyexplained/hydropower/
- HydroSource
  https://hydrosource.ornl.gov/
- National Hydropower Association
  https://www.hydro.org/
- Hydropower Market Report
  https://www.energy.gov/sites/prod/files/2021/01/f82/us-hydropower-market-report-full-2021.pdf
- Hydropower Geotechnical Foundations: Executive Summary
  https://info.ornl.gov/sites/publications/Files/Pub142905.pdf
- Six Non-Power Benefits of Hydropower
  https://www.energy.gov/eere/articles/six-non-power-benefits-hydropower
- A Review of Technology Innovations for Pumped Storage Hydropower
  https://www.osti.gov/biblio/1867238-review-technology-innovations-pumped-storage-hydropower

[109] https://www.eia.gov/energyexplained/hydropower/where-hydropower-is-generated.php.
[110] https://www.energy.gov/eere/articles/six-non-power-benefits-hydropower.
[111] https://www.energy.gov/sites/prod/files/2019/09/f66/73355-v2.pdf.

- Portal and Repository for Information on Marine Renewable Energy (PRIMRE)
  https://openei.org/wiki/PRIMRE
- Marine Energy Collegiate Competition Resources
  https://openei.org/wiki/PRIMRE/STEM/Marine_Energy_Collegiate_Competition_(MECC)/Resources
- Marine Energy Resource Library
  https://openei.org/w/images/3/3f/Marine_Energy_Resource_Library_MECC.pdf
- Powering the Blue Economy
  https://www.energy.gov/eere/water/powering-blue-economy