NREL Transforming ENERGY

2022 ARPA-E Innovation Summit

ARPA-E Funded Projects

Economic Long-Duration Electricity Storage by Using Low-Cost Thermal Energy Storage and High-Efficiency Power Cycle (ENDURING)

Zhiwen Ma, Booth 225

This project is developing the ENDURING energy storage system to provide power for 10 to 100 hours using low-cost, high-performance storage cycles. This system addresses grid storage needs and enables large-scale grid integration of intermittent renewables like wind and solar to increase their grid value.

RePED 250 Drilling Tool: A Revolutionary, High-Drilling-Rate, High-T Geothermal Drilling System and Companion (250–350°C) Power Electronics

Devon Kesseli, Booth 1125

Drilling rates through the crystalline rock found in geothermal fields are much slower than those seen in the sedimentary rock found in oil and gas fields, which produces elevated drilling costs. The RePED 250 drilling system uses pulsed power to crush rocks in tension, rather than compression, which will significantly increase drilling speeds, improve project economics, and increase geothermal deployment in the United States. This project focuses on the development of high-temperature power electronics (such as switches, capacitors, and alternators) to enable drilling in high-temperature geothermal zones. It will impact additional applications, including fuel cells, electric vehicles, aviation, smart grids, and oil and gas drilling.

An Integrated Paradigm for the Management of Delivery Risk in Electricity Markets: From Batteries to Insurance and Beyond

Elina Spyrou, Booth 922

As the electricity generated by variable resources increases, power system operators and variable resources have to manage challenging imbalances between day-ahead and real-time markets. This project designs and analyzes Flexibility Options, a novel day-ahead electricity market product that addresses previously overlooked short-term hedging needs of uncertain and flexible resources. To include distributed energy resources (DERs) as suppliers of flexibility options, the project also investigates the development of scores that will help quantify flexibility from a heterogeneous fleet of DERs.

End-to-End Optimization for Molecular and Atomistic Systems

Peter St. John, Booth 910

Using techniques from reinforcement learning and high-throughput quantum mechanics calculation, this project focuses on creating scalable molecular and inorganic material structure optimization software. This software is demonstrated on two challenging example material optimization problems: first, the design of active species for organic stable radical redox flow batteries, and second, the design of stable electrolyte interfaces for solid-state batteries.

Inverse Network Transformations for Efficient Generation of Robust Airfoil and Turbine Enhancements (INTEGRATE)

Ganesh Vijayakumar, Booth 204

The INTEGRATE project is developing a new inverse-design capability for the aerodynamic design of wind turbine rotors using invertible neural networks. This artificial intelligence (AI)-based design technology can capture complex nonlinear aerodynamic effects while being 100 times faster than design approaches based on computational fluid dynamics. This project enables innovation in wind turbine design by accelerating time to market through higher-accuracy early design iterations to reduce the levelized cost of energy.

Formate as an Energy Source To Allow Sugar Fermentation With No Net CO_2 Generation: Integration of Electrochemistry With Fermentation

Randy Cortright

This project combines the technical and commercial expertise of two commercial partners from different industrial sectors (Genomatica for fermentation and De Nora for electrochemical processing) working with NREL and the University of Oregon to develop an integrated process that converts sugars to lipids. This final lipid product will be an ideal feedstock for existing renewable diesel and sustainable jet fuel technologies. The main innovation of this project will be using electrochemically generated formate as an energy carrier that will provide the necessary reducing equivalents for the fermentation of sugars to lipids without the net generation of CO_2 from the combined processes.

Advanced Locomotive Technology and Rail Infrastructure Optimization System

Jason Lustbader, Booth 903

The Advanced Locomotive Technology and Rail Infrastructure Optimization System (ALTRIOS) is a unique, fully integrated, open-source software tool to evaluate strategies for deploying advanced locomotive technologies and associated infrastructure for cost-effective decarbonization. ALTRIOS will simulate energy conversion and storage dynamics, locomotive and train dynamics, meet-pass planning (detailed train timetabling), and freight-demand-driven train scheduling in a Pareto optimization. Because new locomotives represent a significant long-term capital investment and new technologies must be thoroughly demonstrated before deployment, this tool will provide guidance on the risk/reward tradeoffs of different technology rollout strategies. An open, integrated simulation tool will be invaluable for identifying future research needs and making decisions on technology development, routes, and train selection. ALTRIOS development is a collaboration between NREL, the University of Illinois Urbana-Champaign RailTEC, Southwest Research Institute, and BNSF.

Current and Tidal Optimization (CT-Opt)

Toan Tran

The CT-Opt project is developing a new, open-source model. This model will allow for the design and optimization of hydrokinetic turbines (HKT) for both riverine and current applications. This project will make control co-design capabilities accessible to enable the most efficient and cost-effective HKT designs, thus increasing the likelihood of robust deployments of these technologies.

Floating Offshore Wind and Controls Advanced Laboratory (FOCAL) Experimental Program

Amy Robertson, Booth 1207

The FOCAL experimental program aims to generate the first public floating offshore wind turbine (FOWT) data set that enables the validation of control co-design capabilities to develop more innovative, cost-effective floating wind designs. To effectively utilize a control co-design approach, current coupled aero-hydro-servo-elastic modeling tools must be improved to include new turbine and platform control techniques and flexibility, and these models must be validated with experimental data. The FOCAL program will generate the needed data through four experimental campaigns using a scale model of the floating International Energy Agency (IEA) Wind 15-MW reference wind turbine, demonstrating the improved performance that can be achieved by employing advanced floating wind turbine controls and floating platform load mitigation technology.

Ultraflexible Smart Floating Offshore Wind Turbine (USFLOWT)

Senu Sirnivas, Booth 1207

The USFLOWT program focuses on completing the design of a radically innovative system to unlock the floating offshore wind market by lowering the cost of energy to 7.5¢/kWh or less. The project will develop this technology through the concurrent design of the floating substructure and an intelligent control system, i.e., control co-design. The technological breakthrough is a bio-inspired, ultra-compliant, modular, and scalable floating substructure for a 10-MW wind turbine.

The Wind Energy With Integrated Servo-Control Toolset (WEIS)

Alan Wright, Booth 1207

This project focuses on developing the Wind Energy With Integrated Servo-Control (WEIS) toolset, a revolutionary open-source toolset designed to enable control co-design of floating offshore wind turbine systems (FOWTS). This user-friendly, open-source, flexible toolset will enable revolutionary new optimized FOWTS to maximize energy capture at greatly reduced costs.

Multiscale Electricity Modeling for Evaluating Carbon Capture and Sequestration Technologies (MEME-CCS)

Stuart Cohen, Booth 835

This project employs a multiscale electricity modeling platform, which includes the PLEXOS production-cost model and the Regional Energy Deployment System (ReEDS) capacity-expansion model, to evaluate the future potential for carbon capture and sequestration (CCS) and negative emissions technologies (NET) being developed under the ARPA-E Flexible Carbon Capture and Storage (FLECCS) program. The team will release new open-source modeling capabilities for representing flexible CCS/NET operation in response to grid system needs, helping an emerging CCS/NET industry understand its future role and potential in the U.S. electricity system.

Synthetic Electric Grid Data for Distribution (Smart-DS) and Demand-Side Participation in Wholesale Markets (Bid-DS)

Bryan Palmintier, Booth 936 (shared)

Smart-DS built multiple very large, open-access, power grid data sets that represent realistic but not real electric distribution systems for Santa Fe, NM; Greensboro, NC; the entire San Francisco Bay Area, CA; and a combined distribution-transmission model for all of Texas. These are up to 10,000x larger than previous test systems, and include unprecedented detail with parcel-driven customers, time series data, voltages from 120V home connections up to transmission, and a rich set of scenarios. The ongoing Bid-DS phase explores demand-side bidding into wholesale electric markets. This includes realistic synthetic participation models for key industries plus aggregated commercial/residential to advance this emerging area and support the upcoming 3rd Grid Optimization competition (GO-3).

PERFORM Probabilistic Wind, Solar, and Load Forecast Datasets

Bri-Mathias Hodge

This project is creating probabilistic wind, solar, and load forecasts and actuals for use by the Performance-Based Energy Resource Feedback, Optimization, and Risk Management (PERFORM) awardee teams. These forecasts will be created at multiple timescales and for multiple geographic regions, in particular, the regions covered by the Electric Reliability Council of Texas, the Midcontinent Independent System Operator, the Southwest Power Pool, and the New York Independent System Operator.

Direct Air Capture to Fuels

Josh Schaidle

Reactive capture of CO_2 is the integration of (1) CO_2 separation from dilute gas streams and (2) conversion of that CO_2 into valuable products without proceeding through purified CO_2 as an intermediate. This reactive capture strategy has several potential advantages over separated capture and utilization processes, including improved energy efficiency by reducing energy input for regeneration of adsorption media and reduced capital expense through process intensification. Utilization of renewable energy inputs also offers the opportunity to generate products at significantly lower carbon intensity than their fossil-derived analogs. The overarching goal of this project is to perform comprehensive process modeling, techno-economic analysis, and life-cycle assessment to evaluate the value proposition of reactive CO_2 capture and its role in carbon drawdown.

WEMS Technology Demonstration and Validation

Kosol Kiatreungwattana

The Mackinac Technology Company has developed a Window Energy Management Systems (WEMS) technology that delivers high thermal insulation performance and dynamic control of solar heat gain. The WEMS technology was selected for demonstration and validation at two U.S. Department of Defense (DoD) installations: the U.S. Air Force Academy in Colorado Springs, Colorado, and the Selfridge Air National Guard Base near Mount Clemens, Michigan. In addition, ARPA-E is collaborating with the General Services Administration for the WEMS technology to be demonstrated and validated at the Federal Center in Denver, Colorado. NREL is providing technical assistance and conducting an independent measurement and verification and a thermal/economic analysis for the WEMS technology.

NREL is also a partner on the following projects.

Electric Flightworthy Lightweight Integrated Thermally Enhanced Powertrain System (eFLITES) for Narrow-Body Commercial Aircraft

Sreekant Narumanchi, NREL

Project Led by General Electric Global Research Center

NREL is contributing to the thermal, thermal-fluids, thermomechanical, and reliability aspects of the inverter and electric motor design, development, and evaluation. In addition, NREL will be evaluating the inverter experimentally and performing techno-economic analysis.

Wide Bandgap Semiconductor Amplifiers for Plasma Heating and Control

Sreekant Narumanchi, NREL

Project Led by Princeton Fusion Systems

NREL is contributing to the thermal and thermal-fluids aspects of the design, development, and evaluation of the boards for plasma heating and control in fusion applications.

Exploring the Limits of Cooling for Extreme Heat Flux Applications: Data Centers and Power Electronics

Sreekant Narumanchi, NREL

Project Led by Stanford University

NREL is contributing to the reliability evaluation of the copper-inverse-opal-based two-phase cooling technology.

20-kV GaN Device Technology Demonstrated in High-Efficiency Medium-Voltage Power Module

Sreekant Narumanchi, NREL

Project Led by Virginia Tech

NREL is contributing to the thermal, thermal-fluids, thermomechanical, and reliability aspects of the power module design, development, and evaluation.

Breaking the Board: Bringing Three-Dimensional Packaging and Thermal Management to Power Electronics

Douglas DeVoto, NREL

Project Led by Synteris

NREL is partnering with Synteris and Packet Digital to develop an additive manufacturing (AM) process to print 3D ceramic packaging for power electronic modules. This proposed concept aims to replace the traditional insulating metalized substrate, substrate attach, and baseplate/heat exchanger with an additively manufactured ceramic component that acts as both an electrical insulator and a heat exchanger for a dielectric fluid.

Substation in a Cable for Adaptable, Low-Cost Electrical Distribution (SCALED)

Douglas DeVoto, NREL

Project Led by Virginia Tech

NREL is contributing to the thermal, thermal-fluids, thermomechanical, and reliability aspects of the SCALED module, a coaxial medium-voltage SiC modular converter topology.

High Power Density Motor Equipped With Additively Manufactured Windings Integrated With Advanced Cooling and Modular Integrated Power Electronics

Kevin Bennion, NREL

Project Led by Marquette

NREL is a partner on the Marquette-led ARPA-E Aviation-Class Synergistically Cooled Electric Motors with iNtegrated Drives (ASCEND) program. The project team will develop a novel integrated motor, power electronics, and a thermal management system to meet or exceed the ASCEND program targets. NREL will perform thermal management modeling, analysis, and characterization of the advanced cooling concepts for the power electronics, electric machine, and thermal management system.

Converting Hydrocarbons to Recyclable, Lightweight Automotive Structures With Positive Hydrogen Output

Jeff Blackburn, NREL

Project Led by Rice University

This project focuses on developing a process to produce low-cost hydrogen at scale and recyclable, lightweight materials to replace metals in automotive applications. The process involves converting natural gas into carbon nanotubes with concurrent production of H2, spinning the nanotubes into fibers, and evaluating the fiber properties with the target of displacing metals.

Scale Model Experiments of Co-Designed FOWTs Supporting a High-Capacity (15-MW) Turbine

Jason Jonkman, NREL

Project Led by Atkins

NREL is providing technical support to Atkins for numerical modeling of the International Energy Agency (IEA) Wind 15-MW reference wind turbine atop the Atkins-designed semisubmersible and tension leg floating platforms in OpenFAST and validation of the OpenFAST models against the tank-test data gathered within the project. NREL is also providing technical support for wind turbine controls design and uncertainty assessment of the tank-test data.

Stochastic Optimal Power Flow

Bernard Knueven, NREL

Project Led by Arizona State University

This joint work between the Midcontinent Independent System Operator (MISO), Arizona State University, Sandia National Laboratories, and Nexant, Inc., evaluates the impact of employing stochastic optimization techniques to MISO's intra-day commitment process to address increasing uncertainty in load, wind generation, and net scheduled interchange. NREL partnered with the team to develop mathematical formulations of and solution methodology for a stochastic look-ahead commitment tool that could be used in place of MISO's existing commitment advisory tool. The team found that leveraging these stochastic optimization techniques could yield a net economic and reliability benefit for MISO.

Context-Aware Learning for Inverse Design in Photovoltaics

Ross Larsen, NREL

Project Led by Iowa State University

This project aims to develop, validate, and bring to market inverse-network machine learning algorithms that will accelerate the selection of materials and manufacturing processes needed to create high-efficiency organic solar cells. NREL is focused on producing experimentally backed, physics-based submodels to train Iowa State University's machine learning framework.

Kyphosid Ruminant Microbial Biodigestion of Seaweeds (KRuMBS)

Lieve Laurens, NREL

Project Led by Ocean Era, Inc.

This project focuses on developing a novel, highly efficient process for the conversion of macroalgal biomass to bioenergy and thus providing a pathway for the monetization of large-scale marine macroalgae aquaculture. NREL is helping to isolate, optimize, and deploy microbial consortia and individual microorganisms capable of rapidly digesting macroalgal biomass in a highly scalable way.

Extending PFSA Membrane Durability Through Enhanced Ionomer Backbone Stability

Hai Long, NREL

Project Led by 3M

NREL is partnering with 3M and General Motors (GM) to develop novel perfluorosulfonic acid (PFSA) fuel cell membranes for use in heavy transportation applications. To guide the synthetic work, NREL is conducting computational modeling that employs density functional theory to study membrane degradation mechanisms. The combination of mechanistic studies, computational modeling, and synthesis of novel ionomers will enable the team to develop new, inherently chemically stable ionomers for use in fuel cell membranes.

Ultra-High-Temperature Ceramic Additively Manufactured Compact Heat Exchangers

Zhiwen Ma, NREL

Project Led by Missouri University of Science and Technology

This project is developing a highly compact, power-dense heat exchanger for lower capital costs and portable/remote power applications. The technology enables higher turbine inlet temperatures and/or decreased cooling, increasing efficiency gains to reduce water consumption and emissions.

Rapidly Viable Sustained Grid

Govind Saraswat, NREL, Booth 929

Project Led by University of Minnesota, Twin Cities

This project develops solutions for rapid viability of power to keep critical infrastructure (like medical centers) online while the grid is restored, possibly after a blackout. NREL leads the development of large-scale power hardware-in-loop experiments using a real-world medical center model with multiple grid-forming inverters, along with the demonstration of seamless transition from grid to local generation. NREL is also developing a fast and optimal net load management module to ensure power to critical loads and to maximize the horizon of viability.

The NASA Floater: 15-MW Ultra-Lightweight Concrete Hull With Seawater Ballast Tuned Mass Dampers

Matt Shields, NREL

Project Led by University of Maine

This project evaluates the ability of novel tuned mass dampers located in the hull to reduce the motion of a floating offshore wind turbine. NREL and the University of Maine have developed an open-loop control scheme that provides control authority by varying the amount of water ballast and compressed air in the dampers as a function of the sea state. The modeled results indicate that the dampers can reduce motion and loads, and unlike conventional methods that rely on rotor control, they can do so while the turbine is parked during extreme weather events.

NREL
Transforming ENERGY

National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

May 2022