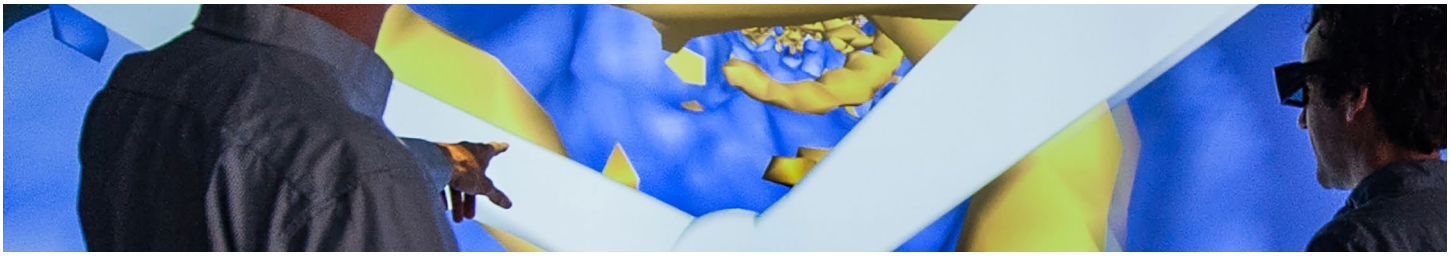
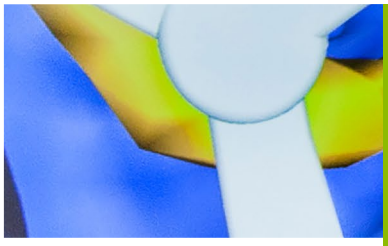
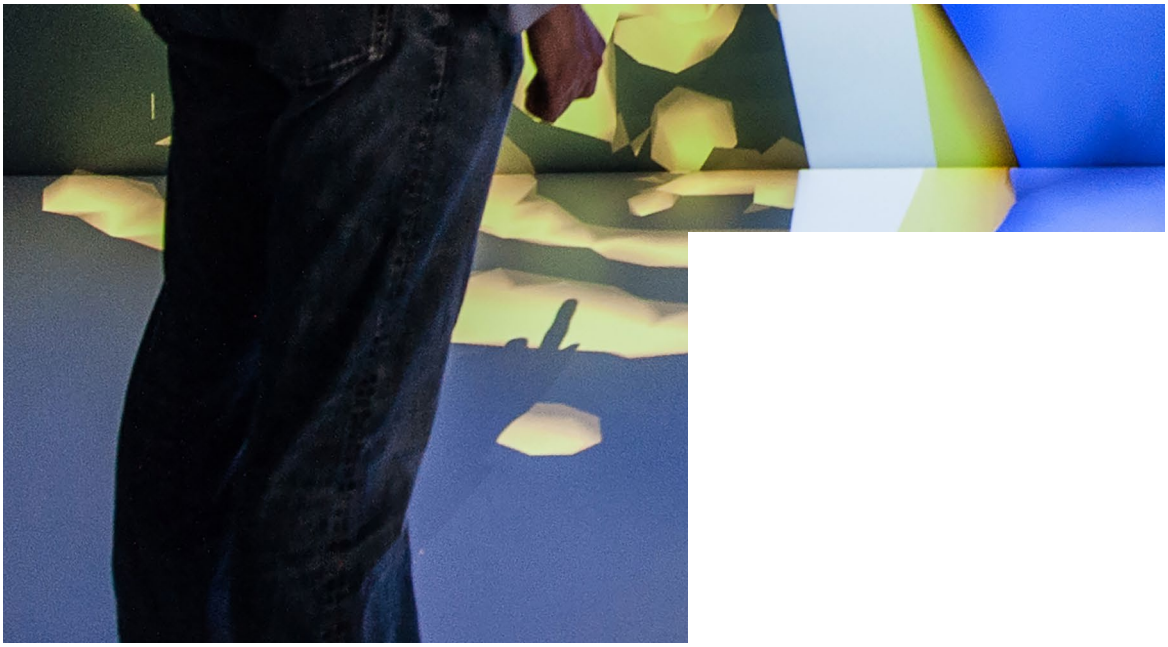


NREL
NATIONAL RENEWABLE ENERGY LABORATORY



ESIF 2015

MID-YEAR REPORT



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.

ASSOCIATE DIRECTOR'S LETTER

Halfway through its second year of operation, the Energy Systems Integration Facility (ESIF) at the National Renewable Energy Laboratory (NREL) continues to rack up successes in the field of energy systems integration (ESI). ESI brings together the wide range of energy carriers—electricity, thermal sources, and fuels—with other infrastructures, such as water and communications. Although most energy sources, delivery systems, and demand-response programs are treated as stand-alone technologies today, ESI examines how they can optimally work together as a system, and the ESIF is a vital tool in exploring these interactions.

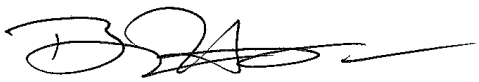
This report provides an overview of recent work at the ESIF from October 2014 to March 2015. The Fiscal Year 2014 ESIF annual report documented more than $5 million in new funds in research with 46 partners. Many of these partnerships continue to be active today as NREL works with utilities, universities, government agencies, other national laboratories, and a variety of industries to investigate all aspects of ESI.

This report documents the new and continuing partnerships that are maintaining a lively pace of activity in the ESIF. It also reports on the latest physical enhancements to the ESIF, including significant new capabilities to generate and store hydrogen and to use it for refueling.

Perhaps most significant of all, ESIF engineers have demonstrated the ability to connect the software modeling and power hardware-in-the-loop capabilities in the ESIF to the NREL National Wind Technology Center (NWTC) and other national laboratories in what is the first step toward creating a larger virtual laboratory capability for ESI. This virtual laboratory could provide a single-point access to all the ESI capabilities available within the U.S. Department of Energy's (DOE's) national laboratory system, yielding a powerful new tool to examine ESI.

NREL continues to welcome new partners to the ESIF, and a variety of partnership agreements are available.

Sincerely,



Bryan Hannegan,
Associate Director for ESI at NREL

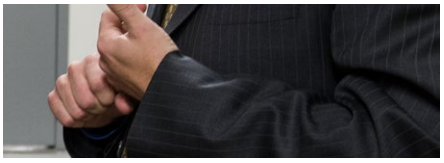
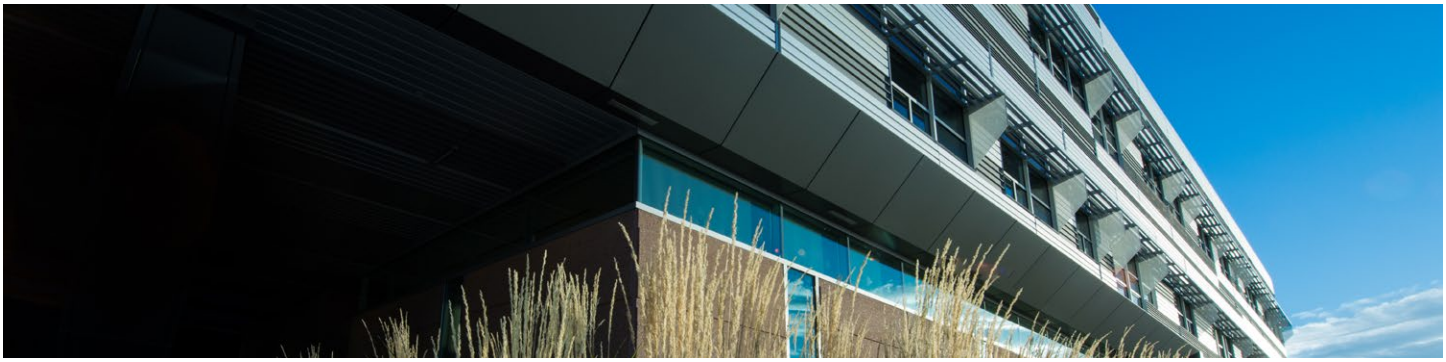


TABLE OF CONTENTS



OVERVIEW—THE FIRST HALF OF FY 2015

The ESIF continues to demonstrate its value in the field of ESI. This report covers the first half of FY 2015, from October 1, 2014, to March 31, 2015. It also marks roughly the first year and a half of operations at the ESIF.

Top accomplishments for the first half of FY 2015 include:

- Twelve new partnerships were started, with the bulk of the work focusing on electric grid issues. NREL is providing critical support for three new microgrid projects, coordinated by the Electric Power Research Institute (EPRI), General Electric (GE), and Raytheon, and also teamed with SolarCity to investigate the operational issues associated with large amounts of solar power on Hawaii's distribution lines. The latter work allowed the Hawaiian Electric Companies (HECO) to permit new solar power installations on distribution lines that have high penetrations of solar power.
- NREL greatly expanded the ESIF's hydrogen energy capabilities, adding a new electrolyzer stack test bed for hydrogen production, systems for cleaning and compressing the hydrogen, and a hydrogen dispensing station for vehicles. NREL also tested the largest-ever polymer electrolyte membrane (PEM) fuel cell stacks, which convert hydrogen and oxygen from the air into electricity, for Giner, Inc.
- The ESIF and its partners at other national laboratories used real-time digital simulators (RTDSs) to connect their hardware and simulation software at a distance. The ESIF was first connected to the controllable grid interface (CGI) at NREL's NWTC. This connection allows for large-scale wind turbines to be connected to simulations and other hardware being tested at the ESIF. The ESIF was also connected to the Idaho National Laboratory (INL) for a two-way exchange of data between actual hardware at INL and a software model at NREL, opening the door for software and equipment anywhere in the world to establish a real-time connection to the unique facilities and capabilities available within the national laboratory complex.
- The Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's science agency, teamed with NREL to conduct testing of a microgrid controller and evaluate the potential effect of high penetrations of solar photovoltaic (PV) power on the Australian electric grid. The specific task was to review the communications protocols needed to enable plug-and-play capabilities for PV power, allowing new PV systems to automatically communicate with the microgrid controller and establish an interconnection with the microgrid. This effort aims to develop an advanced solar microgrid controller that automatically recognizes and optimizes new solar power sources.

Lab Stats

Sponsor: U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE)

Location: Golden, Colorado, on the campus of DOE's National Renewable Energy Laboratory (NREL)

Size: 182,500 square feet

AWARDS AND RECOGNITIONS

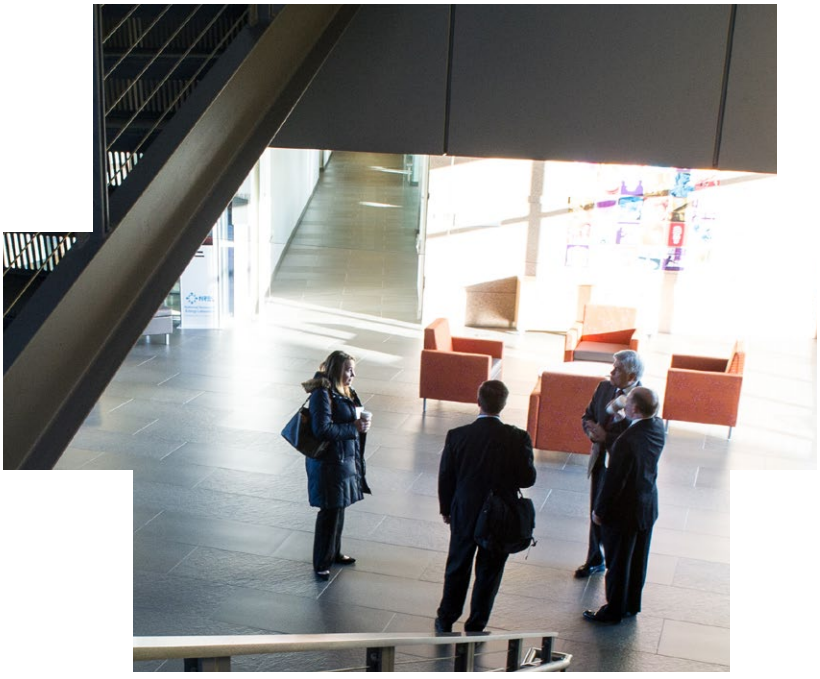
ESIF Data Center Garners 2014 DOE Sustainability Award

Peregrine—the ultraefficient data center in the ESIF—has been recognized by DOE with a 2014 Sustainability Award for its novel approach to energy reduction. The ultraefficient ESIF data center developed by Hewlett-Packard features a chiller-less design, warm-water liquid cooling, an annual average power usage effectiveness (PUE) of 1.06, and waste heat capture and reuse—making it the world's most energy-efficient data center.

NREL's complete approach to sustainability allowed the data center to fully integrate into the facility, ensuring that the computer systems and data center have a symbiotic relationship with the ESIF's mechanical systems rather than trying to optimize each in isolation. NREL's approach to data center sustainability demonstrates technologies that save energy and water, reduce carbon dioxide emissions, and capture and reuse waste heat.

Top Honors Go to NREL Supercomputing Achievements

At the 2014 International Conference for High Performance Computing, Networking, Storage and Analysis on November 17 in New Orleans, Louisiana, NREL and Texas Advanced Computing Center at the University of Texas at Austin received the HPCwire 2014 Editors' Choice Award for Top Supercomputing Achievement for groundbreaking research in converting biomass to biofuels. This is significant because although NREL's new facility and high performance computing (HPC) system have been recognized recently for their advances in energy efficiency, this HPCwire award recognizes how these HPC resources are being used to advance important areas of science and technology.



DOE PROGRAM RESEARCH

In the first half of FY 2015, NREL initiated DOE program research with a total value of more than $19 million in the ESIF laboratories, including these projects:

Transportation & Hydrogen Systems

- Evaluation of Electric Trucks
- Catalysts and Electrodes
- Particle Receiver Testing
- Fuel Cell R&D
- System, Stack, and Component Operation and Performance
- Testing and Technical Assessment
- Enlarging Potential National Penetration for Stationary Fuel Cells through System Design and Optimization
- Renewable Electrolysis: Integrated Systems Development and Testing
- Hydrogen Dispenser Hose Reliability Improvement
- NREL Fuel Cell Manufacturing QC R&D
- Fuel Cell Vehicle Demonstration

Buildings & Thermal Systems

- Degradation Mechanisms and Development of Protective Coatings for TES and HTF Containment Materials
- Consulting to Zero-Energy Community Developer
- Cost-Optimal New Construction Practices

National Wind Technology Center

- Upgrade to GE 1.5-MW Wind Turbine

Energy System Integration Facility

- Intelligent Power and Energy Management Microgrid Testing
- Army Rapid Equipping Force Reliability and Engineering Analysis
- 300-kW, 386-kWh Battery Energy Storage System
- Distributed Intelligence Platform Reference Architecture Demonstration
- 1-kVDC Inverter Testing
- Power-to-Gas Demonstration
- Cohesive Application of Standards-Based Connected Devices to Enable Clean Energy Technologies

Power Systems Engineering

The Google High Power Density Inverter Prize: Innovation in PV Inverter Power Density

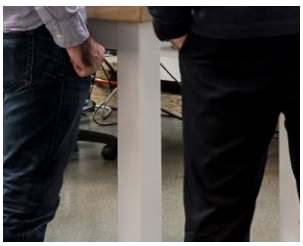
Residential PV Energy Storage Testing Collaboration with SunPower

Computational Sciences

Visualization and Simulation of Manufacturing Line

Chemistry and Nanoscience

Ammonia Synthesis for Fertilizers at Low Pressure and Temperature



DOE PROGRAM RESEARCH HIGHLIGHTS

INTEGRATE Focuses on Solutions to the Escalation of Renewable Energy on the U.S. Electric Grid

NREL is managing the Integrated Network Testbed for Energy Grid Research and Technology Experimentation (INTEGRATE) project, and all five technical teams will test their technologies in NREL's unique megawatt-scale ESIF. The teams include Omnetric Corporation, Duke Energy, CPS Energy, and the University of Texas at San Antonio. Each of the cost-shared projects will address the challenge of enabling the nation's electric grid to handle increasing amounts of renewable energy.

NREL and INL Demonstrate Power Grid Simulation at a Distance

NREL and INL have successfully demonstrated the capability to connect grid simulations at their two labs for real-time interaction via the Internet. This new inter-lab capability enables modeling power grids in greater detail by allowing software and equipment anywhere in the world to establish a real-time connection to the unique facilities and capabilities available within DOE's national laboratory complex.

Future experiments will match the utility-scale transmission system at INL to a simulated distribution line at NREL, which will be connected to an electrolyzer that produces hydrogen from electricity. If the electrolyzer is turned down to consume less electricity, that change in operation will be reflected in the distribution line simulation, which will relay its response to the INL system. Then the INL transmission line will respond appropriately to that change. To make the power flows work out, the local Colorado grid will provide power for the electrolyzer, while the local Idaho grid will absorb the power produced by INL's transmission system.

NREL to Provide Critical Support to Two New Microgrid Projects Coordinated by EPRI and GE

NREL will test microgrid controllers developed by EPRI and GE at the ESIF using its megawatt-scale power hardware-in-the-loop capability. Power hardware-in-the-loop allows researchers and manufacturers to conduct integration tests at full power and actual load levels in real-time simulations to evaluate component and system performance before going to market.

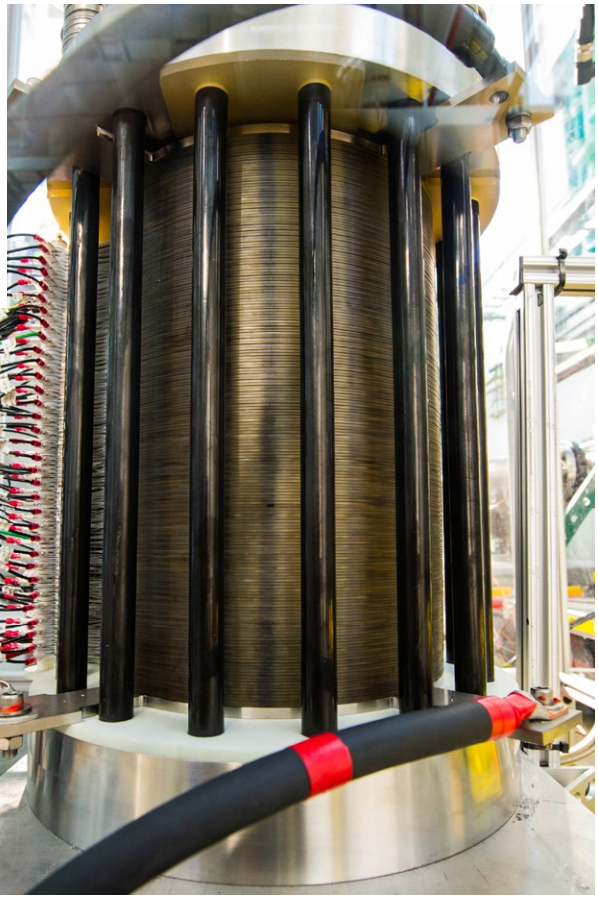
Simulator Training Enables NREL Engineers to Model Effects of Renewable Energy Systems on the Grid

NREL held a training workshop at the NWTC for a new real-time hardware-in-the-loop simulator. The system was purchased as part of the INTEGRATE project with the goal of allowing engineers and operators at both the NWTC and the ESIF to run near-real-time models of the electric grid. The models will allow NREL researchers to simulate operation of the national electric grid while introducing the effects of renewable energy sources such as solar and wind. These simulations will help inform research on the introduction of large amounts of renewable generation into the grid while maintaining grid stability.

The hardware has real-world input/output to field turbines and dynamometer test articles at the NWTC as well as test articles and simulations at the ESIF. Eventually, the systems at the NWTC and the ESIF will be able to communicate with the CGI and dynamometer test facilities at Clemson University in South Carolina and at INL to expand the scope of DOE's grid modeling capability.

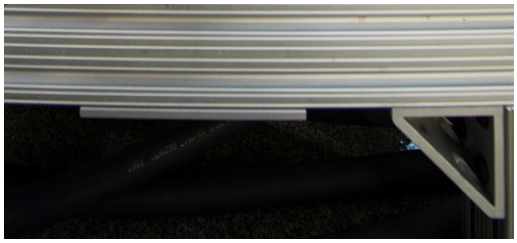
Distributed Energy Resource Management System Opens Up Communications Channels

NREL partnered with EPRI to develop a distributed energy resource management system, or DERMS, that would allow distributed energy resources to "talk" to other systems or entities, providing information about demand, supply, and use of electricity. The research and development effort was the culmination of several years of coordinated work with numerous industry stakeholders and builds off the original development of smart inverter standards. NREL hosted a workshop with representatives from Schneider Electric, Boreas Group, Nebland Software, Spirae, and Smarter Grid Solutions. Reps were either in attendance or testing CIM or MultiSpeak messages, while some did both. This workshop proved the capability of an architecturally-agnostic DERMS to support the various use cases that the team identified.



Hydrogen Infrastructure Testing and Research Facility Primed to Begin Fueling Vehicles

Designed by NREL researchers, the Hydrogen Infrastructure Testing and Research Facility (HITRF) consists of storage, compression, and dispensing capabilities for fuel cell vehicle refueling and component testing. It is the first facility of its kind in Colorado and will be available to industry for use in research and development activities. Integrated with the ESIF, the HITRF provides a hydrogen distribution network to multiple labs researching hydrogen production through renewable electrolysis, fuel cell manufacturing and testing, high-pressure component testing, and hydrogen sensor testing. The station is representative of current commercially available hydrogen fueling stations, enabling NREL to validate current industry standards and methods for hydrogen fueling as well as perform testing for next-generation technology and controls. In anticipation of vehicle fueling, dispenser commissioning and safety checks were performed, and the dispenser was successfully integrated with the HITRF control system in March 2015.



PARTNERSHIP HIGHLIGHTS

When NREL researchers and scientists support industry innovators, the achievements can have a broad and lasting impact. Here are some highlights of the great work performed with industry partners at the ESIF in the first half of FY 2015.

NREL Teams with SolarCity and HECO to Maximize Solar Power on Electric Grids

NREL collaborated with SolarCity and HECO at the ESIF to address the safety, reliability, and stability challenges of interconnecting high penetrations of distributed PV with the electric power system.

For this project, NREL researchers used the ESIF's unique power hardware-in-the-loop technology to analyze how various PV inverters interacted with the electric grid in critical areas such as transient overvoltage, multi-inverter unintentional islanding, and voltage regulation. NREL also evaluated SolarCity's PV generation curtailment hardware and software.

Based on the results of testing at the ESIF, HECO has announced they will more than double circuit thresholds to 250% of daytime minimum load and approve PV deployments for customers who have been waiting for interconnection to these high-penetration solar circuits.

This research was supported by the Office of Energy Efficiency and Renewable Energy's and DOE's Grid Modernization Initiative. Funding was equally shared between SolarCity and DOE's SunShot Initiative.

Raytheon and NREL Demonstrate Advanced Microgrid System

NREL has partnered with Raytheon, Primus Power, and Advanced Energy to successfully demonstrate an advanced microgrid system that draws on batteries and solar energy for its power.

To test this technology, NREL built a replica of the microgrid system in the ESIF and tested it in both islanded and grid-connected modes, including the transition between modes. Researchers evaluated the efficacy of the microgrid controller in managing PV power output and battery charging and discharging under various solar penetration and power quality scenarios. This testing allowed researchers to demonstrate the actual performance of the system prior to its installation at Marine Corps Air Station (MCAS) Miramar.

The demonstration proved that an energy storage system-driven microgrid with conventional PV inverters can achieve 100% PV penetration while retaining the power quality needed to satisfy critical facility loads, reducing operational costs, logistical burden, and carbon footprint. Using this pilot system's technology, the fielded microgrid at MCAS Miramar will be able to maintain power to base facilities under many adverse conditions—including loss of the local power grid.

NREL Partners with Southern California Gas Company to Launch First Power-to-Gas Project in U.S.

Southern California Gas Company has joined with NREL and the National Fuel Cell Research Center to launch demonstration projects to create and test a carbon-free, power-to-gas system for the first time ever in the United States. The technology converts electricity into hydrogen and methane and could provide North America with a large-scale, cost-effective solution for storing excess energy produced from renewable sources.

Using electrolyzer-based methods, the power-to-gas concept uses electricity from renewable sources, such as solar and wind power, to make carbon-free hydrogen gas by breaking down water into hydrogen and oxygen. The hydrogen can then be converted to synthetic, renewable methane (traditional natural gas) and stored to meet future energy needs. It can also be used as a multipurpose energy source for vehicles, micro-turbines, fuel cells, or other equipment.

NREL Works with Erigo and EaglePicher to Test Microgrid Energy Storage System

NREL researchers are helping to test an energy storage system developed by Erigo and EaglePicher and sponsored by U.S. Northern Command that contains three independently controllable energy storage technologies.

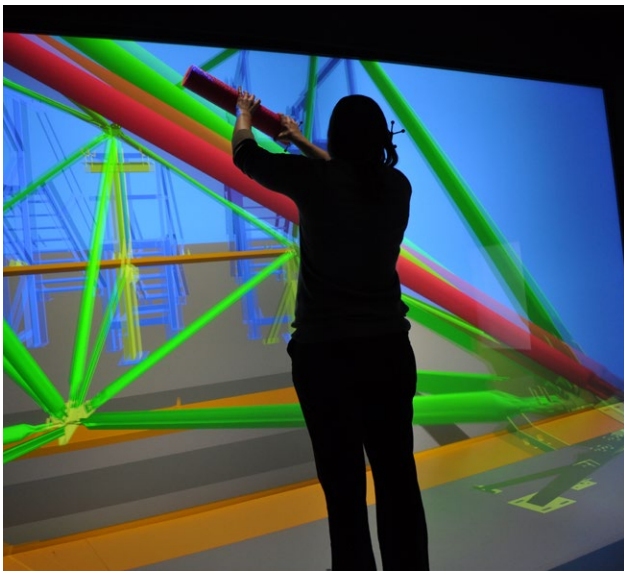
The system has been installed at the ESIF, and researchers are completing basic functionality validation and performance characterization in a variety of operational modes representative of historical and anticipated military base microgrid demands. The system will also be integrated into microgrid applications and other scenarios a military base might encounter.

Microgrids—and effective storage systems supporting them—are especially important for remote military bases where accessing energy can be costly and dangerous. This research will demonstrate new test methods and platforms to assess battery systems in microgrid applications, leading to improved design and efficiency.

Abengoa Optimizes a New Assembly Method for Concentrating Solar Power Parabolic Troughs at the ESIF's Insight Center

NREL is collaborating with Abengoa at the ESIF to develop a new, more cost-effective manufacturing process for critical components of concentrating solar power systems.

Abengoa researchers were able to model their assembly method design in the ESIF's Insight Center using 3D visualization to allow engineers to see and interact with their CAD models at a 1:1 scale. With an immersive virtual environment like the Insight Center, engineers are able to work within their design at full scale before the prototype stage, which allows them to identify and eliminate design flaws earlier. This results in drastically reduced prototyping costs and helps companies like Abengoa to lower the cost of solar technologies by achieving efficiencies in the manufacturing process.



Giner and NREL Validate Large-Scale Hydrogen PEM Electrolyzer

Giner collaborated with NREL to test a large-scale PEM electrolyzer designed to maximize renewable energy on the grid by converting it to hydrogen when supply exceeds demand.

Researchers validated the electrolyzer stack's performance under varying power conditions to demonstrate the capability of the technology to provide grid services, energy storage, and emissions-free transportation fuel for fuel cell electric vehicles.

Megawatt-scale electrolyzers offer the potential for utilities to rely more heavily on renewable energy sources because the electrolyzers are able to capture and store excess energy as hydrogen. Connecting electrolyzers to the grid would make it easier for utilities to add more renewables to their mix because extra energy could be absorbed—not lost—during times of high output or low demand.

PG&E and Efficient Drivetrains Collaborate with NREL to Test Plug-in Hybrid Electric Utility Truck

NREL performed testing and analysis on a Pacific Gas and Electric (PG&E) plug-in hybrid electric utility truck developed by Efficient Drivetrains, Inc., that has approximately 30 miles of all-electric range and is capable of exporting up to 120 kW of AC power to the grid.

Using the ESIF's drive-in thermal chamber and research utility system, NREL researchers conducted testing and analysis to improve understanding of the truck's export power mode and onboard thermal control under a variety of environmental conditions.

With utility trucks that have onboard, exportable power capabilities, companies like PG&E would be able to power a small neighborhood or commercial building while repairs are made upstream on the grid, shortening or eliminating outage time. Testing at the ESIF will help developers fine-tune the design and reliability of the trucks' exportable power features before they are placed into service.

PARTNERS

NREL continues to forge new partnerships across industry, academia, and government to leverage the expert staff and exceptional resources that the ESIF offers. Below are partners with active agreements in the first half of FY 2015.

3M*
Abengoa Solar
Advanced Energy Industries
Alstom
American Vanadium
Arizona Public Service
Asetek
The Babcock and Wilcox Company
CellEra
Clemson University
Colorado School of Mines*
CPS Energy
CSIRO*
Denver Water
Duke Energy*
EaglePicher Technologies
Efficient Drivetrains
Electric Power Research Institute*
Element One, Inc.
Energy Storage Systems
Electric Reliability Council of Texas
Erigo
General Electric
General Motors
Giner, Inc.*
Google*
HOUZE*
Ingersoll Rand
KPA
Mercedes-Benz
Nanosonic
Netherlands Enterprise Agency (RVO)
New Jersey Institute of Technology
Omnetric Group
Pacific Gas and Electric
Parker Hannifin Corp.*
PDC Machines, Inc.
Proton OnSite
Raytheon
Sandia National Laboratories
San Diego Gas & Electric*
SolarCity*
Solectria Renewables*
Southern California Edison
Southern California Gas
Spectrum Automation Controls*
Spirae
Strategic Analysis, Inc.
SunPower
Technical University of Denmark
Toyota North America*
University of California, Irvine
University of Colorado, Boulder*
University of Delaware
University of Texas at San Antonio
University of Wisconsin
Wells Fargo
Wyle

* These partners have more than one project.

NEW PARTNERSHIPS

NREL's work with industry and academia continues to grow through forward-looking partnerships and projects. New partnership agreements were signed with **Arizona Public Service, Clemson University, EPRI/Spirae, Electric Reliability Council of Texas, GE, HOUZE, Ingersoll Rand, Mercedes-Benz, Nanosonic, San Diego Gas & Electric, the Technical University of Denmark, and Wells Fargo/Energy Storage Systems** in the first half of FY 2015. Below are a few highlights of new projects that will soon be underway at the ESIF.

Denver Water

NREL will collaborate with Denver Water—the water utility for 1.3 million people in and around Denver, Colorado—to examine new ways for water systems to save energy. Energy accounts for 5%–30% of the total operating costs for water utilities because energy is needed for nearly every step in the water supply cycle, but water systems also have the potential to generate electricity. This interrelationship between energy and water is now being referred to as the "energy-water nexus," and NREL and Denver Water intend to gain a greater understanding of that nexus, including ways that the energy and water infrastructures can work together more efficiently.

Arizona Public Service

The Arizona Public Service Company has signed a technical services agreement with NREL to develop a way for utilities to better evaluate requests for interconnecting PV systems onto the utility's distribution feeders. A common problem with interconnecting large PV inverters on distribution feeders is that the PV systems may drive up daytime voltages on the feeder line, causing voltage regulators on that line to cycle excessively and perhaps fail prematurely. NREL will provide a practical methodology for evaluating the technical and financial options for mitigating such operational impacts.

The Technical University of Denmark

NREL will work with the Technical University of Denmark as an industrial partner for the Centre for IT-Intelligent Energy Systems in Cities (CITIES) Project. Denmark is targeting an energy system that is completely renewable. To reach this ambitious goal, CITIES is bringing together industrial and academic partners to effectively overhaul and integrate Denmark's energy system. NREL will provide technical support for this project, including modeling, simulating, and analyzing integrated energy systems.

CAPABILITY UPGRADES

Real-Time Data Link Between INL and NREL

NREL and INL have successfully demonstrated the capability to connect grid simulations at their two labs for real-time interaction via the Internet. The two national laboratories were able to connect their real-time digital simulators and achieve grid simulation so hardware or software in one lab can directly interact with the hardware or software at the other lab. While connected, the local power electronics handle any actual power flows into and out of the hardware. INL has multiple RTDS racks that can be interfaced to NREL's grid simulator, allowing the simultaneous simulation of complex power systems that have many electrical buses and multiple distribution feeders.

Megawatt-Scale Islandable Microgrid Demonstration Setup

NREL created a microgrid test environment for Raytheon's microgrid power and control system. The ESIF microgrid installation was designed to mimic a planned microgrid at MCAS Miramar by using two 100-kW AE100TX solar inverters; a 1,600-A microgrid switch; a 540-kVA bidirectional grid simulator; two solar simulator DC power supplies to simulate the Miramar PV array at power; a 1,000-VDC battery simulator power supply; and a 200-kW load bank. Using this setup, NREL was able to simulate the battery working at full power, replicate a variable solar energy supply over time, and re-create the loads on the system based on the actual loads measured at MCAS Miramar. The simulated microgrid was tested in both grid-connected and off-grid or "islanded" modes, and the efficacy of the microgrid controller was evaluated on an intra-laboratory communications network designed and validated for this activity. NREL monitored the controller's ability to manage PV output power and battery charging and discharging to maximize the use of solar power.

Microgrid Energy Storage

A 300-kW, 400-kWh microgrid energy storage system designed to provide grid services as well as support critical loads during emergency conditions has been installed at the ESIF's Medium Voltage Outdoor Test Area. The system was developed by EaglePicher and Erigo and funded by the U.S. Department of Defense (U.S. Northern Command). NREL will assist with demonstrating the system and use the system for integrated testing in the ESIF over the coming year.

Large-Scale Hydrogen Production Electrolyzer Stack Test Bed

NREL designed, built, and now operates an electrolyzer stack test bed that provides on-site hydrogen production for fuel cell labs, hydrogen component testing research, and fuel cell electric vehicle refueling. The test bed was designed for hydrogen production in the range of 100 kilograms per day. It is already operating at approximately half that capacity with a 120-kW PEM stack purchased from Proton OnSite.

Hydrogen Vehicle Fueling Station

NREL designed, built, and commissioned a dual-pressure (350/700-bar) hydrogen fueling system. The system compresses and stores hydrogen fed from the electrolyzer stack test bed up to 400 bar (80 kg capacity at 6,000 psig). Another compression stage can then elevate the pressure to 875 bar (30 kg capacity at approximately 13,000 psig), where it is stored for vehicle refueling. The fueling system precools the hydrogen gas to refuel a vehicle in approximately 3 minutes. At 350 bar, it could provide fuel for two fuel cell electric forklifts and hydrogen-power buses; at 700 bar, it will be used for fuel cell electric vehicle refueling and to test and validate the reliability of hydrogen fueling components such as hoses, compressors, and pressure safety valves.

Hydrogen Component Test Beds

NREL has successfully employed two high-pressure hydrogen test bays for the first time. The test bays can accommodate research and development of hydrogen components at up to approximately 13,000 psig. One of the test beds includes thermal cycling to simulate ambient temperature fluctuations. The other one features low-temperature (-40°C) cooling of the hydrogen gas to simulate real-life component stresses associated with hydrogen refueling.

Capability Hub Configuration

To accommodate new projects, NREL has laid out plans for 26 purpose-built spaces throughout the ESIF's laboratories. These "capability hubs" will allow greater flexibility in the use of lab space and a more efficient distribution of the lab's testing resources. Each hub will be connected to equipment for a specific testing purpose and can be interconnected with other equipment and parts of the lab to create an integrated system. Planned hubs include residential inverter-in-the-loop test bays, a large-scale electrolyzer demand management test bed, and a medium-voltage capacitor bank test area.

USER FACILITY UPDATES

NREL Selects Demonstration Projects for INTEGRATE Project

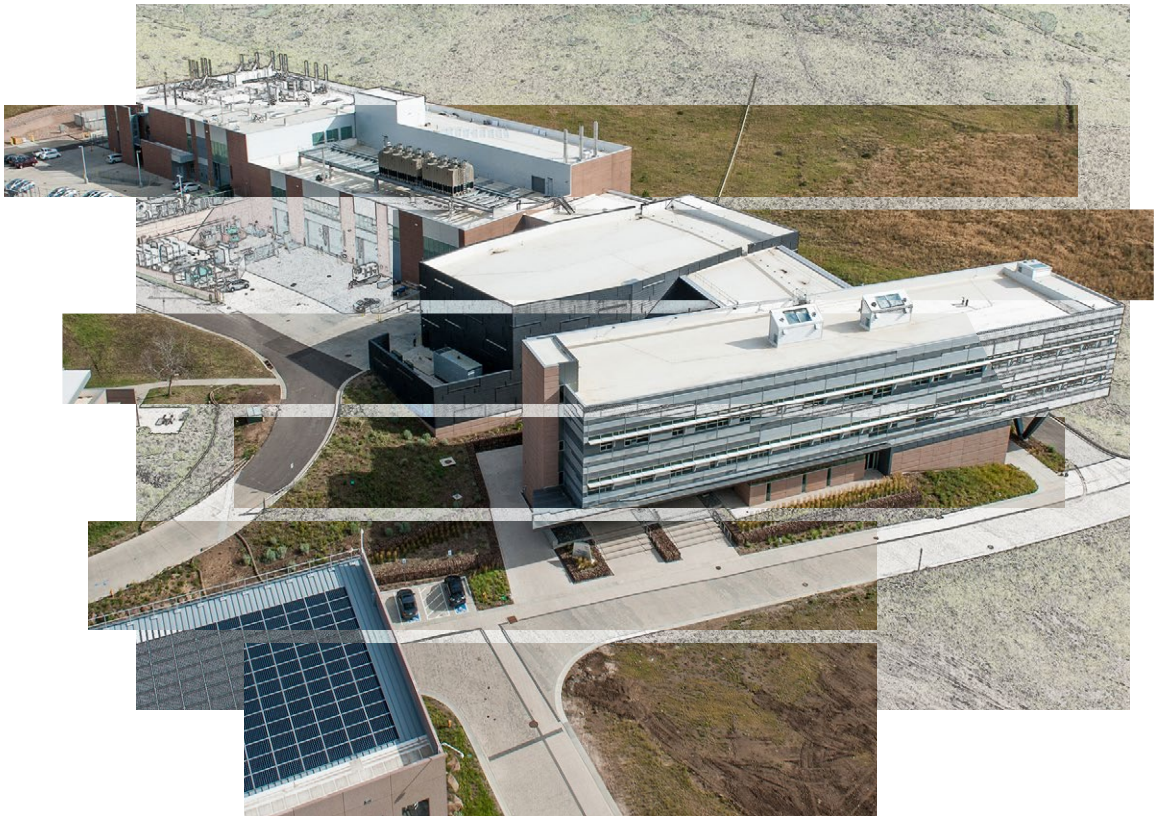
NREL has selected five demonstration projects to be installed and evaluated in the ESIF as part of a request for proposals for the INTEGRATE project. Each project addresses one of three targeted topic areas: connected devices, communications and control systems, and integrated systems. These demonstration projects will begin in Q2 and Q3 of FY 2015, and they will be completed during the next 18 months. The goal of the INTEGRATE project is to support the development and validation of open-source, interoperable technologies that can increase the hosting capacity of the grid.

Enhancements Incorporated into Online User Support System

Leveraging a framework developed by Pacific Northwest National Laboratory, NREL has adapted and improved its online user support system to provide greater functionality and a better user experience. The system is currently being used to process FY 2015 resource requests for shared equipment and work space. The goal is to have all ESIF users, including NREL staff, submit and manage their resource requests through this system.

NREL Publishes ESIF User Guide

The ESIF User Program team has developed and published an ESIF User Guide. This booklet is designed to be a quick reference for new users of the ESIF and provides essential information about working safely in the ESIF labs, required trainings, campus policies and procedures, and what to do in case of an emergency.



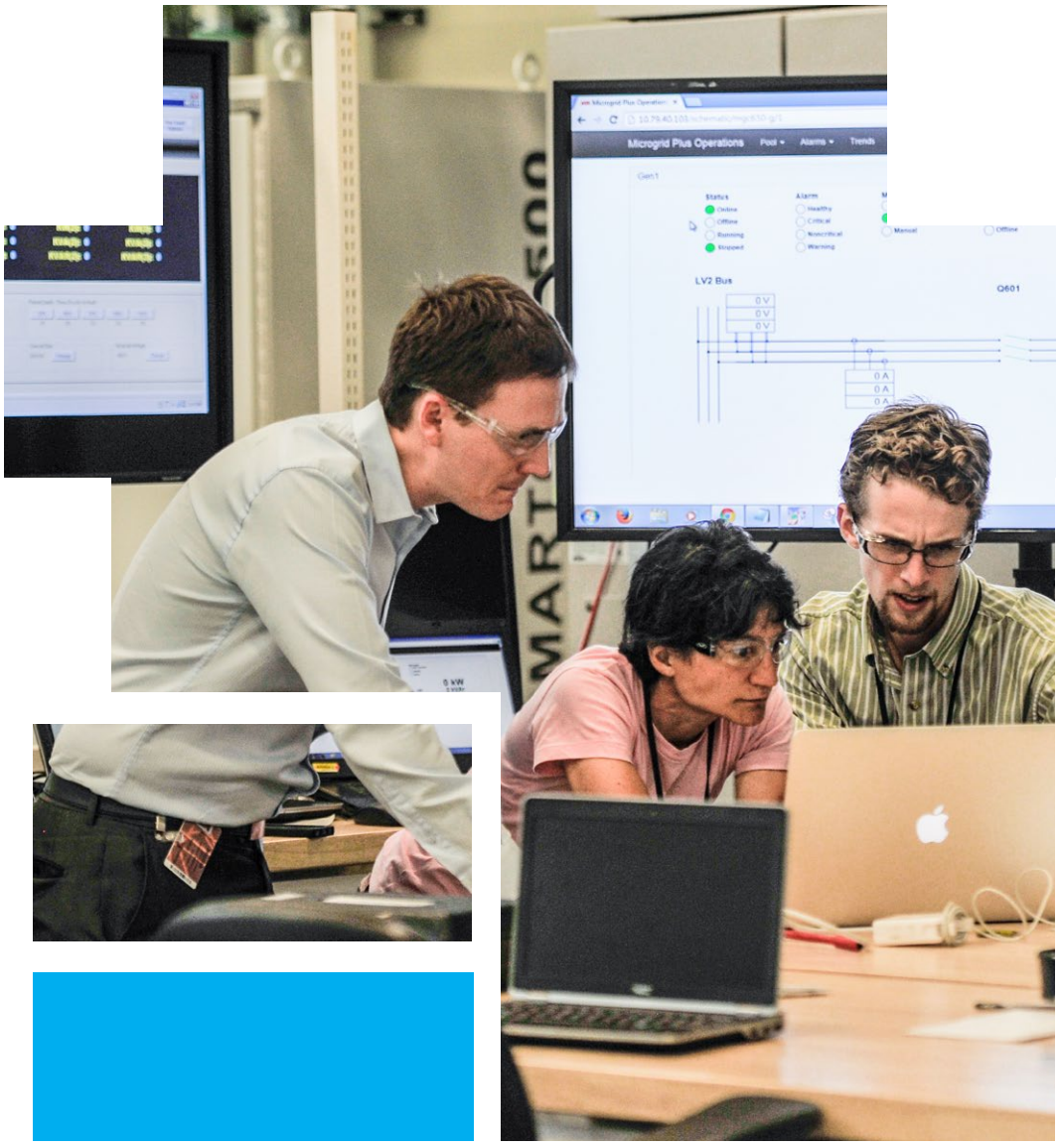
INVENTIONS

Licenses

ESIF Capability/ Resource Used	Title	NREL Number	Contributor Name
Lab	Grid-Friendly System for Implementing High-Penetration Distributed PV with Storage	ROI-15-10	Jeremy Neubauer
Lab	Hydrogen Removal from Solar Thermal Power Plants	ROI-15-28	Greg Glatzmaier
Lab	Integrated Energy System Model	SWR-15-07	Annabelle Pratt, Wesley Jones, Monte Lunacek, Mark Ruth, Hongyu Wu, and Saurabh Mittal
Lab	Method and Apparatus for Rapid Measurement of Solar Simulator Uniformity	ROI-15-05	Timothy Silverman
Lab	U-Cavity Receiver Design and Operation for Solid-Particle-Based Concentrating Solar Power Plant	ROI-15-27	Zhiwen Ma and Janna Martinek
HPC	Acceptor-Donor-Acceptor Type Polymers as Electron Donors in Organic Photovoltaic Bulk Heterojunctions	ROI-15-48	Dana Olson, Ross Larsen, and Zbyslaw Owczarczyk
HPC	ED-SVM, Fluent CAEBAT API	SWR-15-04	Peter Graf, Gi-Heon Kim, and Kandler Smith
Other	glmgen	SWR-15-01	Elaine Hale, Bryan Palmintier, and Timothy Hansen
Other	H2FAST (hydrogen financial analysis scenario tool)	SWR-15-06	Brian Bush, Michael Penev, and Marc Melaina
Other	Home Energy Management System	SWR-15-12	Annabelle Pratt, Hongyu Wu, and Sudipta Chakraborty
Other	Integrated Grid Modeling System	SWR-15-08	Elaine Hale, Bryan Palmintier, Timothy Hansen, Wesley Jones, Harry Sorensen, and David Biagioni
Other	Radiometer Calibration and Characterization —Windows Version	SWR-15-02	Chet Wells (retired), Afshin Andreas, Ibrahim Reda, Stephen Wilcox (retired), Thomas Stoffel (retired), Daryl Myers (retired), and Gene Maxwell (retired)
Other	Smartphone- and Wearables-Based Building Energy Management	ROI-15-52	Xin Jin, Lieko Earle, Mo Sha, and Bethany Sparn
Other	Zoned, Modular, Combination HVAC Heat Pump and Heat Pump Water Heater System	ROI-15-19	Chuck Booten and Dane Christensen

Patents Filed

ESIF Capability/ Resource Used	Title	NREL Number	Inventor Name
Lab	Batch and Continuous Methods for Evaluating the Physical and Thermal Properties of Thin Films	PROV-14-68	Michael Penev, Bhushan Sopori, Michael Ulsh, Przemyslaw Rupnowski, and Guido Bender
Lab	Platinum Nickel Nanowires as Oxygen-Reducing Electrocatalysts and Methods of Making the Same	PROV-14-41	Shaun Alia and Bryan Pivovar



PUBLICATIONS

ESIF Laboratory Publications

Journal Articles

Alia, S.M.; Pylypenko, S.; Neyerlin, K.C.; Kocha, S.S.; Pivovar, B.S. (2014). "Nickel Nanowire Oxidation and Its Effect on Platinum Galvanic Displacement and Methanol Oxidation." NREL/JA-5900-63856. *ECS Transactions* (3); pp. 89-95. http://ecst.ecsdl.org/content/64/3/89.

Buttner, W.J.; Burgess, R.; Rivkin, C.; Post, M.B.; Boon-Brett, L.; Palmisano, V.; Moretto, P. (2014). "Assessment on the Quantification of Hydrogen Releases through Oxygen Displacement Using Oxygen Sensors." NREL/JA-5400-61075. *International Journal of Hydrogen Energy* (39:35) December; pp. 20484-20490. http://www.sciencedirect.com/science/article/pii/S036031991400980X.

Cho, H.S.; Das, M.; Wang, H.; Dinh, H.N.; Van Zee, J.W. (2015). "Contamination Mechanism and Behavior of Amide Bond Containing Organic Contaminant on PEMFC." NREL/JA-5900-62537. *Journal of the Electrochemical Society* (162:4); pp. F427-F435. http://jes.ecsdl.org/content/162/4/F427.

Christ, J.M.; Neyerlin, K.C.; Richards, R.; Dinh, H.N. (2014.) "Concentration Effects of Polymer Electrolyte Membrane Degradation Products on Oxygen Reduction Activity for Three Platinum Catalysts." NREL/JA-5900-62445. *Journal of the Electrochemical Society* (161:14); pp. F1360-F1365. http://jes.ecsdl.org/content/161/14/F1360.

Christ, J.M.; Neyerlin, K.C.; Wang, H.; Richards, R.; Dinh, H.N. (2014). "Impact of Polymer Electrolyte Membrane Degradation Products on Oxygen Reduction Reaction Activity for Platinum Electrocatalysts." NREL/JA-5900-62449. *Journal of the Electrochemical Society* (161:14); pp. F1481-F1488. http://jes.ecsdl.org/content/161/14/F1481.

Decegelie, M.G.; Silverman, T.J.; Emery, K.; Dirnberger, D.; Schmid, A.; Barkaszi, S.; Riedel, N.; Pratt, L.; Doshi, S.; Tamizhmani, G.; Marion, B.; Kurtz, S.R. (2015). "Validated Method for Repeatable Power Measurement of CIGS Modules Exhibiting Light-Induced Metastabilities." NREL/JA-5J00-63237. *IEEE Journal of Photovoltaics* (5:2) March; pp. 607-612. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6994210.

Long, H.; Pivovar, B.S. (2015). "Hydroxide Degradation Pathways for Substituted Benzyltrimethyl Ammonium: A DFT Study." NREL/JA-2C00-62672. *ECS Electrochemistry Letters* (4:1); pp. F13-F16. http://eel.ecsdl.org/content/4/1/F13.

Palmintier, B.; Lundstrom, B.; Chakraborty, S.; Williams, T.; Schneider, K.; Chassin, D. (2015). "Power Hardware-in-the-Loop Platform With Remote Distribution Circuit Cosimulation." NREL/JA-5D00-61697. *IEEE Transactions on Industrial Electronics* (62:4); pp. 2236-2245. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6949628.

Palmisano, V.; Boon-Brett, L.; Bonato, C.; Harskamp, F.; Buttner, W.J.; Post, M.B.; Burgess, R.; Rivken, C. (2014). "Evaluation of Selectivity of Commercial Hydrogen Sensors." NREL/JA-5400-61200. *International Journal of Hydrogen Energy* (39:35) December; pp. 20491–20496. http://www.sciencedirect.com/science/article/pii/S0360319914009793.

Sturgeon, M.R.; Macomber, C.S.; Engtrakul, C.; Long, H.; Pivovar, B.S. (2015). "Hydroxide Based Benzyltrimethylammonium Degradation: Quantification of Rates and Degradation Technique Development." NREL/JA-5900-63275. *Journal of the Electrochemical Society* (162:4); pp. F366-F372. http://jes.ecsdl.org/content/162/4/F366.

Conference Papers (Papers Only)

Hoke, A.; Chakraborty, S.; Basso, T. (2014). "Testing Advanced Photovoltaic Inverters Conforming to IEEE Standard 1547 - Amendment 1." *Proceedings of the 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC);* June 8-13, 2014, Denver, CO. NREL/CP-5D00-61205. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1014-1021. DOI:10.1109/PVSC.2014.6925086.

Marion, B.; Anderberg, A.; Deline, C.; del Cueto, J.; Muller, M.; Perrin, G.; Rodriguez, J.; Rummel, S.; Silverman, T.J.; Vignola, F.; Kessler, R.; Peterson, J.; Barkaszi, S.; Jacobs, M.; Riedel, N.; Pratt, L.; King, B. (2014). "New Data Set for Validating PV Module Performance Models." *Proceedings of the 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC);* June 8-13, 2014, Denver, CO. NREL/CP-5J00-61179. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1362-1366. DOI:10.1109/PVSC.2014.6925171.

Panwar, M.; Suryanarayanan, S.; Chakraborty, S. (2014). "Steady-State Modeling and Simulation of a Distribution Feeder with Distributed Energy Resources in a Real-Time Digital Simulation Environment." *Proceedings of the 2014 North American Power Symposium (NAPS);* September 7-9, 2014, Pullman, WA. NREL/CP-5D00-62381. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1-6. DOI:10.1109/NAPS.2014.6965445.

Silverman, T.J.; Deceglie, M.G.; Marion, B.; Kurtz, S.R. (2015.) "Performance Stabilization of CdTe PV Modules Using Bias and Light." *Proceedings of the 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC);* June 8-13, 2014, Denver, CO. NREL/CP-5J00-63144. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 344-349. DOI:10.1109/PVSC.2014.6924904.

Williams, T.; Fuller, J.; Schneider, K.; Palmintier, B.; Lundstrom, B.; Chakraborty, S. (2014). "Examining System-Wide Impacts of Solar PV Control Systems with a Power Hardware-in-the-Loop Platform." *Proceedings of the 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC);* June 8-13, 2014, Denver, CO. NREL/CP-5D00-61287. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 2082-2087. DOI:10.1109/PVSC.2014.6925336.

Technical Papers

Andreas, A.M., technical contact. (2015). *Improved Rotating Shadowband Radiometer Measurement Performance: Cooperative Research and Development Final Report.* CRADA Number CRD-08-294. NREL/TP-5D00-63769. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/63769.pdf.

Nelson, A.; Hoke, A.; Chakraborty, S.; Chebahtah, J.; Wang, T.; Zimmerly, B. (2015). *Inverter Load Rejection Over-Voltage Testing: SolarCity CRADA Task 1a Final Report.* NREL/TP-5D00-63510. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/63510.pdf.

Pesaran, A.; Ban, C.; Burton, E.; Gonder, J.; Grad, P.; Jun, M.; Keyser, M.; Kim, G.H.; Neubauer, J.; Santhanagopalan, S.; Saxon, A.; Shi, Y.; Smith, K.; Sprague, M.; Tenent, R.; Wood, E.; Yang, C.; Zhang, C.; et al. (2015). *NREL Energy Storage Projects: FY2014 Annual Report.* NREL/TP-5400-63420. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/63420.pdf.

Posters

Habte, A.; Sengupta, M.; Reda, I. (2015). "A Method to Estimate Uncertainty in Radiometric Measurement Using the Guide to the Expression of Uncertainty in Measurement (GUM) Method." March 2015. NREL/PO-5D00-63900. http://www.nrel.gov/docs/fy15osti/63900.pdf.

ESIF High Performance Computing Data Center Publications

Conference Papers (Papers Only)

Weissbach, R.; Wang, W.L.; Hodge, B.M.; Tang, M.H.; Sonnenmeier, J. (2014). "Generation of Simulated Wind Data using an Intelligent Algorithm." *Proceedings of the 2014 North American Power Symposium (NAPS);* September 7-9, 2014, Pullman, WA. NREL/CP-5D00-60981. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1-6. DOI:10.1109/NAPS.2014.6965405.

Technical Papers

Sickinger, D.; Van Geet, O.; Ravenscroft, C. (2014). *Energy Performance Testing of Asetek's RackCDU System at NREL's High Performance Computing Data Center.* NREL/TP-2C00-62905. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/62905.pdf.

Other

Ela, E.; Kirby, B.; Krad, I.; Gevorgian, V. (2014). "Section 5: Analysis of Steady-State Reliability and Detailed Costs Using the FESTIV Model." *Modeling and Analysis of Value of Advanced Pumped Storage Hydropower in the United States.* NREL/CH-5D00-60469.

ESIF Secure Data Center Publications

Technical Papers

Kurtz, J.; Saur, G.; Sprik, S.; Ainscough, C. (2014). *Backup Power Cost of Ownership Analysis and Incumbent Technology Comparison*. NREL/TP-5400-60732. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy14osti/60732.pdf.

Fact Sheets

Fuel Cell Technology Status Analysis Project: Partnership Opportunities. (2014). This fact sheet describes the National Renewable Energy Laboratory's (NREL's) Fuel Cell Technology Status Analysis Project. NREL is seeking fuel cell industry partners from the United States and abroad to participate in an objective and credible analysis of commercially available fuel cell products to benchmark the current state of the technology and support industry growth. NREL/FS-5400-62944. http://www.nrel.gov/docs/fy15osti/62944.pdf.

ESIF Researcher Publications (Non-Lab)

Journal Articles

Long, H.; Pivovar, B.S. (2014). "Computational Modeling of Degradation of Substituted Benzyltrimethyl Ammonium." NREL/JA-2C00-63926. *ECS Transactions* (64:3); pp. 1211-1219. http://ecst.ecsdl.org/content/64/3/1211.

Sturgeon, M.R.; Macomber, C.S.; Engtrakul, C.; Pivovar, B.S. (2014). "Baseline BTMA Degradation as a Standard for Cationic Degradation in AEMFCs." NREL/JA-5900-62344. *ECS Transactions* (64:3); pp. 1201-1209. http://ecst.ecsdl.org/content/64/3/1201.

Wheeler, D.; Ulsh, M. (2014). "Manufacturing Readiness and Cost Impacts for PEM Stack and Balance of Plant." NREL/JA-5900-63957. *ECS Transactions* (64:3); pp. 897-908. http://ecst.ecsdl.org/content/64/3/897.

Conference Papers (Papers Only)

Baggu, M.; Ayyanar, R.; Narang, D. (2014). "Feeder Model Validation and Simulation for High-Penetration Photovoltaic Deployment in the Arizona Public Service System." *Proceedings of the 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC);* June 8-13, 2014, Denver, CO. NREL/CP-5D00-61129. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 2088-2093. DOI:10.1109/PVSC.2014.6925337.

Cale, J.; Palmintier, B.; Narang, D.; Carroll, K. (2014). "Clustering Distribution Feeders in the Arizona Public Service Territory." *Proceedings of the 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC);* June 8-13, 2014, Denver, CO. NREL/CP-5D00-63534. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 2076-2081. DOI:10.1109/PVSC.2014.6925335.

Dooraghi, M.; Habte, A.; Reda, I.; Sengupta, M.; Gotseff, P.; Andreas, A. (2014). "Quantifying the Impact of Incidence-Angle Dependence on Solar Radiometric Calibration." *Proceedings of the 2014 IEEE 40th Photovoltaic Specialist Conference (PVSC);* June 8-13, 2014, Denver, CO. NREL/CP-5D00-62116. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 2662-2667. DOI:10.1109/PVSC.2014.6925477.

Genc, S.; Baggu, M. (2014). "Look Ahead Volt/VAR Control: A Comparison of Integrated and Coordinated Methods." *Proceedings of the 2014 IEEE PES T&D Conference and Exposition;* April 14-17, 2014, Chicago, IL. NREL/CP-5D00-63307. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1-5. DOI:10.1109/TDC.2014.6863263.

Girsang, I.P.; Dhupia, J.; Singh, M.; Gevorgian, V.; Muljadi, E.; Jonkman, J. (2014). "Impacts of Providing Inertial Response on Dynamic Loads of Wind Turbine Drivetrains." *2014 IEEE Energy Conversion Congress and Exposition (ECCE);* September 14-18, 2014, Pittsburgh, PA. NREL/CP-5D00-63405. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1507-1514. DOI:10.1109/ECCE.2014.6953597.

Habte, A.; Sengupta, M.; Reda, I.; Andreas, A.; Konings, J. (2014). "Calibration and Measurement Uncertainty Estimation of Radiometric Data: Preprint." NREL/CP-5D00-62214. http://www.nrel.gov/docs/fy15osti/62214.pdf.

Ibanez, E.; Milligan, M. (2014). "Comparing Resource Adequacy Metrics and Their Influence on Capacity Value." *Proceedings of the 2014 International Conference on Probabilistic Methods Applied to Power Systems (PMAPS);* July 7-10, 2014, Durham, United Kingdom. NREL/CP-5D00-63647. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1-6. DOI:10.1109/PMAPS.2014.6960610.

Jin, X.; Maguire, J.; Christensen, D. (2014). "Model Predictive Control of Heat Pump Water Heaters for Energy Efficiency." N*ext Generation: Reaching for High Energy Savings: Proceedings of the 2014 ACEEE Summer Study on Energy Efficiency in Buildings;* August 17-22, 2014, Pacific Grove, CA. NREL/CP-5500-61505. Washington, DC: American Council for an Energy-Efficient Economy; pp. 133-145. http://www.aceee.org/files/proceedings/2014/data/papers/1-296.pdf#page=1.

Palmintier, B. (2014). "Flexibility in Generation Planning: Identifying Key Operating Constraints." *Proceedings of the 2014 Power Systems Computation Conference (PSCC);* August 18-22, 2014, Wroclaw, Poland. NREL/CP-5D00-62131. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1-7. DOI:10.1109/PSCC.2014.7038323.

Thomas, J.J.; Grijalva, S. (2014). "Increasing Transmission Capacity Utilization using Power Flow Routers." *Proceedings of the 2014 IEEE PES T&D Conference and Exposition;* April 14-17, 2014, Chicago, IL. NREL/CP-5D00-63326. Piscataway, NJ: Institute of Electrical and Electronics Engineers; pp. 1-5. DOI:10.1109/TDC.2014.6863560.

Technical Papers

Allen, A.; Singh, M.; Muljadi, E.; Santoso, S. (2014). *PMU Data Event Detection: A User Guide for Power Engineers.* NREL/TP-5D00-61664. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/61664.pdf.

Anderberg, M.; Sengupta, M. (2014). *Comparison of Data Quality of NOAA's ISIS and SURFRAD Networks to NREL's SRRL-BMS.* NREL/TP-5D00-62526. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/62526.pdf.

Basso, T. (2014). *IEEE 1547 and 2030 Standards for Distributed Energy Resources Interconnection and Interoperability with the Electricity Grid.* NREL/TP-5D00-63157. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/63157.pdf.

Muljadi, E.; Singh, M.; Gevorgian, V. (2014). *User Guide for PV Dynamic Model Simulation Written on PSCAD Platform.* NREL/TP-5D00-62053. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/62053.pdf.

Neubauer, J.; Simpson, M. (2015). *Deployment of Behind-The-Meter Energy Storage for Demand Charge Reduction.* NREL/TP-5400-63162. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/63162.pdf.

Reda, I.; Dooraghi, M.; Habte, A. (2014). *NREL Pyrheliometer Comparisons: September 22-26, 2014 (NPC-2014).* NREL/TP-3B10-63050. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/63050.pdf.

Rivkin, C.; Burgess, R.; Buttner, W. (2015). *Hydrogen Technologies Safety Guide.* NREL/TP-5400-60948. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy15osti/60948.pdf.

Fact Sheets

Making Fuel Cells Cleaner, Better, and Cheaper. (2015). This NREL S&T Highlights describes NREL work to reduce contaminants in fuel cells, enabling the industry to cut costs and commercialize state-of-the-art technologies. NREL/FS-5900-63382. http://www.nrel.gov/docs/fy15osti/63382.pdf.

Presentations

Gevorgian, V. (2014). "NREL's Controllable Grid Interface for Testing Renewable Energy Technologies." Presented at the Second International Workshop on Grid Simulator Testing of Wind Turbine Drivetrains, September 17, 2014, North Charleston, SC. NREL/PR-5D00-62998. http://www.nrel.gov/docs/fy15osti/62998.pdf.

Other

U.S. Department of Energy Hydrogen and Fuel Cells Program 2014 Annual Merit Review and Peer Evaluation Report: June 16-20, 2014, Washington, D.C. DOE/GO-102014-4503.

Miscellaneous

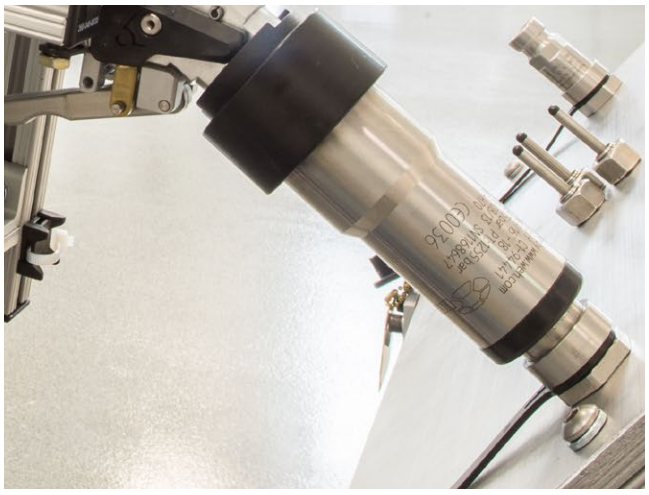
Conference Papers

Scheib, J.; Pless, S.; Torcellini, P. (2014). "Energy-Performance-Based Design-Build Process: Strategies for Procuring High-Performance Buildings on Typical Construction Budgets." *Next Generation: Reaching for High Energy Savings: Proceedings of the 2014 ACEEE Summer Study on Energy Efficiency in Buildings;* August 17-22, 2014, Pacific Grove, CA. NREL/CP-5500-63122. Washington, DC: American Council for an Energy-Efficient Economy; pp. 306-321. http://www.aceee.org/files/proceedings/2014/data/papers/4-643.pdf#page=1.

Sheppy, M.; Torcellini, P.; Gentile-Polese, L. (2014). "Analysis of Plug Load Capacities and Power Requirements in Commercial Buildings." *Next Generation: Reaching for High Energy Savings: Proceedings of the 2014 ACEEE Summer Study on Energy Efficiency in Buildings;* August 17-22, 2014, Pacific Grove, CA. NREL/CP-5500-61528. Washington, DC: American Council for an Energy-Efficient Economy; 13 pp. http://www.nrel.gov/docs/fy14osti/61528.pdf.

Torcellini, P.; Sheppy, M.; Deru, M.; Milan, M. (2014). "Attacking Plug Loads: A Campaign to Deploy Automated Plug Strip Controllers." *Next Generation: Reaching for High Energy Savings: Proceedings of the 2014 ACEEE Summer Study on Energy Efficiency in Buildings;* August 17-22, 2014, Pacific Grove, CA. NREL/CP-5500-61676. Washington, DC: American Council for an Energy-Efficient Economy; pp. 380-391. http://www.aceee.org/files/proceedings/2014/data/papers/9-397.pdf#page=1.


EPSON
WARNING
2
ESIL



Photos by Dennis Schroeder, except where otherwise noted.

Cover, NREL 31413, back cover, NREL 26385. Page 2-3, NREL 29577, NREL 27750. Page 4-5, NREL 29568. Page 6-7, NREL 32580. Page 8-9, NREL 32597. Page 10-11, Photo courtesy of Abengoa. Page 12-13, NREL 32534. Page 14-15, NREL 32466, NREL 28212. Page 16-17, Photo by John De La Rosa, NREL 33659, NREL 30735. Page 18-19, NREL 31611. Page 22-23, NREL 33366.

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

NREL/BR-5C00-64703 • July 2015