SIRFN Capability Summary
National Renewable Energy Laboratory, Golden, CO, USA

Introduction

The National Renewable Energy Laboratory (NREL) is the U.S. Department of Energy's primary national laboratory for renewable energy and energy efficiency R&D.

Several major facilities on the NREL campus provide research, development, testing, and analyses on a wide range of Smart Grid applications at various scales:

- The **Energy Systems Integration Facility** (ESIF) enables Smart Grid equipment to be tested on a plug-and-play basis at megawatt levels.
- The **Distributed Energy Resources Test Facility** (DERTF) assists the power industry in developing and testing small-scale distributed power systems.
- The **controllable grid interface** (CGI) at the **National Wind Technology Center** (NWTC) is a test bed for evaluating multi-megawatt power systems.
- Research at the **Thermal Test Facility** (TTF) focuses energy demand and improving cost effectiveness of energy management technologies to enhance the Smart Grid.
- The **Vehicle Testing and Integration Facility** (VTIF) assess technologies designed to enable PEV communication and two-way interconnection with the Smart Grid.

SIRFN subtasks of interest to NREL and the facilities fully-equipped to support these areas of research on the NREL campus are:

- Renewable Energy and DER Integration – ESIF, CGI at NWTC, DERTF
- Buildings Automation – ESIF, TTF
- PEV Integration – ESIF, VTIF
- Microgrids – ESIF, DERTF, CGI at NWTC

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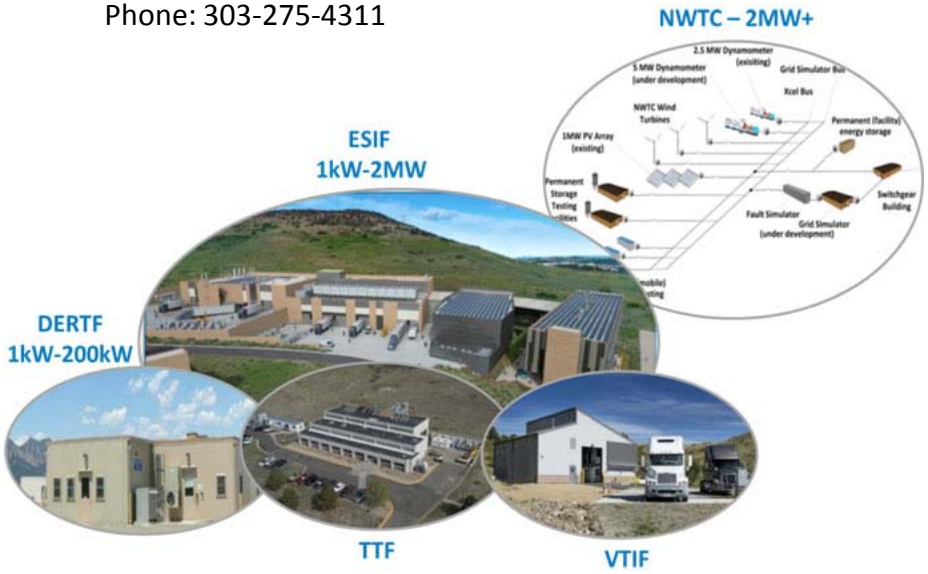

http://www.nrel.gov/esi/facilities.html

SIRFN Subtask 2.1

Renewable Energy and DER Integration

Desired Level of SIRFN Participation: **3**

1 = Low 2 = Med 3 = High

Description of Activities

NREL conducts a wide range of research to support high penetration of renewable energy and distributed energy resources at the distribution level. Researchers work on advanced approaches to interconnection and control technologies, energy management, and grid support applications. This work includes:

- Researching a variety of Smart Grid technologies to allow communications and controls between smart devices
- Developing and testing of codes and standards for Smart Grid interoperability and interconnection of distributed resources
- Researching advanced grid configurations like microgrids and hybrid power system
- Testing and evaluation of interconnection and Smart Grid technologies
- Developing and testing advanced power electronic interfaces for distributed energy applications
- Studying the integration of renewables with electrolyzers
- Characterizing plug-in and hybrid electric vehicles for compatibilities with the grid.

Research, development, and testing are conducted at 3 supporting facilities at NREL:

- **DERTF -** Testing microgrids up to 200kW; grid simulators, load banks, actual wind turbines and PV systems available
- **ESIF -** Low voltage (600V and under) and medium voltage (15kV and under) test areas; flexible connections for electrical, thermal, fuel, and data infrastructures
- **CGI at NWTC -** 7MW grid simulation; access to MW scale wind turbines; MV distribution system

SIRFN Site Focus Area Lead:

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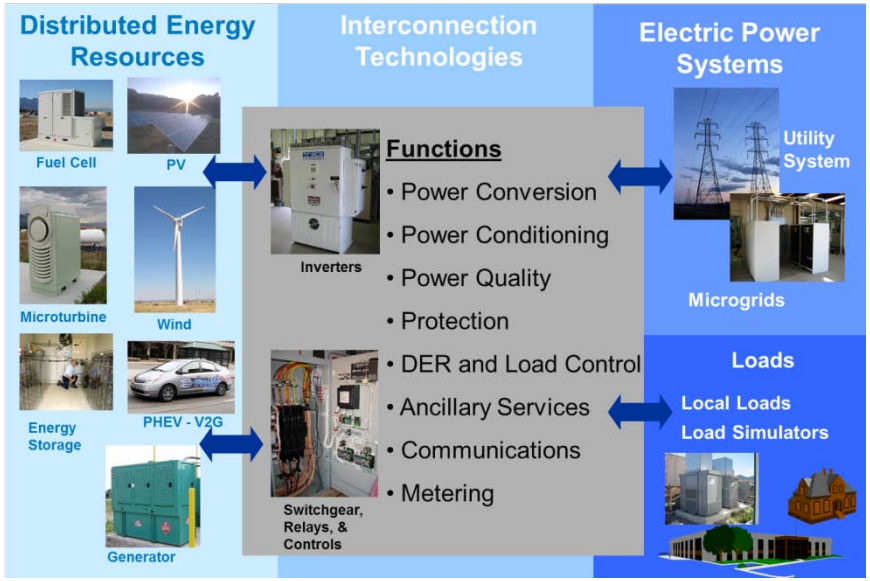

Buildings Automation

Desired Level of SIRFN Participation: **3**

1 = Low 2 = Med 3 = High

Description of Activities

NREL's research in the area of Building Automation focuses on enabling system-wide integration of Smart Grid and demand response products that also help homeowners achieve their cost- and energy-saving goals. Activities include:

- Evaluation of building and component sensing and diagnostics technologies
- Grid responsive strategies for energy and cost savings and load shifting
- Implementation and testing of end-use controls and interoperability
- Feedback and device-level communications
- Characterizing effects of consumption and conservation on larger energy systems
- Newer control approaches for smart energy management devices and systems.

NREL's research, development, and testing activities in the area of Building Automation are supported by the Automated Home Energy Management (AHEM) lab in the TTF and the Smart Power lab in the ESIF.

The labs incorporate all major and minor residential energy loads into a robust test bed that supports the evaluation of any type of residential automation, sensor, or energy management product in a realistic context. Any product developed for home sensing, energy management, and control can be studied at multiple scales, from component to whole-house to community level.

SIRFN Site Focus Area Lead:

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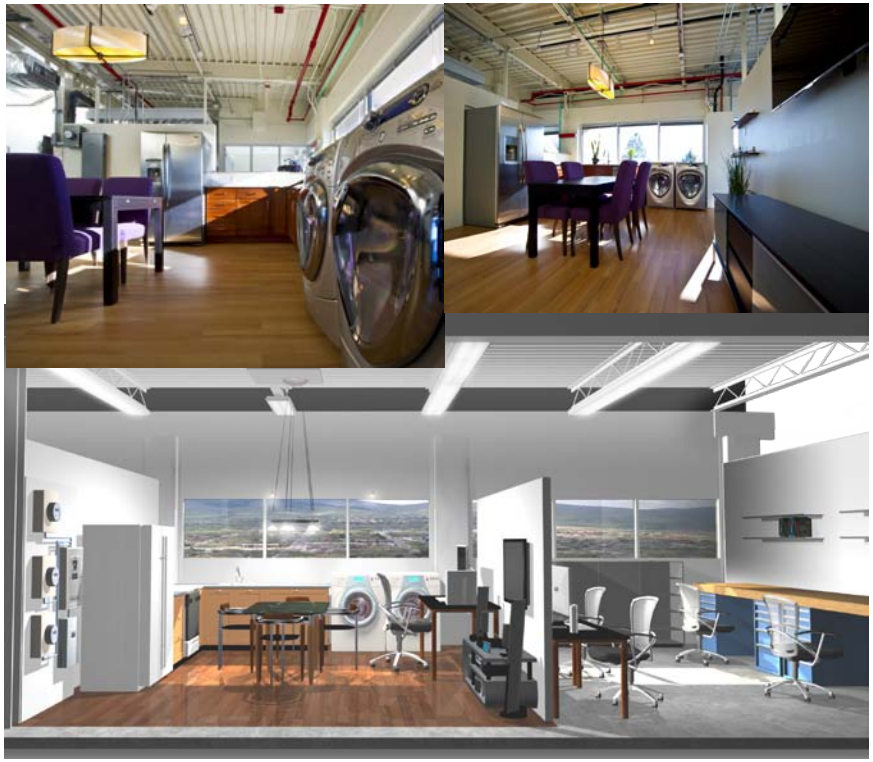

PEV Integration

Desired Level of SIRFN Participation: 3

1 = Low 2 = Med 3 = High

Description of Activities

NREL's research in electric vehicle grid integration supports the development of transportation electrification and the expansion of renewable generation through:

- Understanding vehicle use profiles, EV benefits, and battery life
- Integrating renewable resources with vehicle charging
- Developing and testing grid interoperability standards
- Exploring grid services technology opportunities
- Integrating electric vehicles into the household profile.

Researchers collaborate with automakers, charging station manufacturers, utilities and fleet operators to conduct research that examines the interaction of building energy systems, utility grids, renewable energy sources and PEVs. With several industry partners, NREL is helping to develop appropriate testing protocols to evaluate the ability to have vehicle charge and discharge power to and from the grid.

NREL's research, development, testing, and demonstration activities in the area of PEV integration are supported by the VTIF and the ESIF. Some key features of the facilities include:

- 3 passenger, 1 heavy vehicle bay for vehicle modifications, instrumentation set-up, and experiments
- 50kW DC fast PEV charger
- 3 outdoor AC Level 2 electric vehicle supply equipment units
- Wireless vehicle charging stations
- 2 AC and DC bus lines to interconnect solar energy sources, vehicles, energy storage, smart grid controls and emulated renewables
- 24 locking high-power outlets to accommodate future EV charging components or renewable energy systems.

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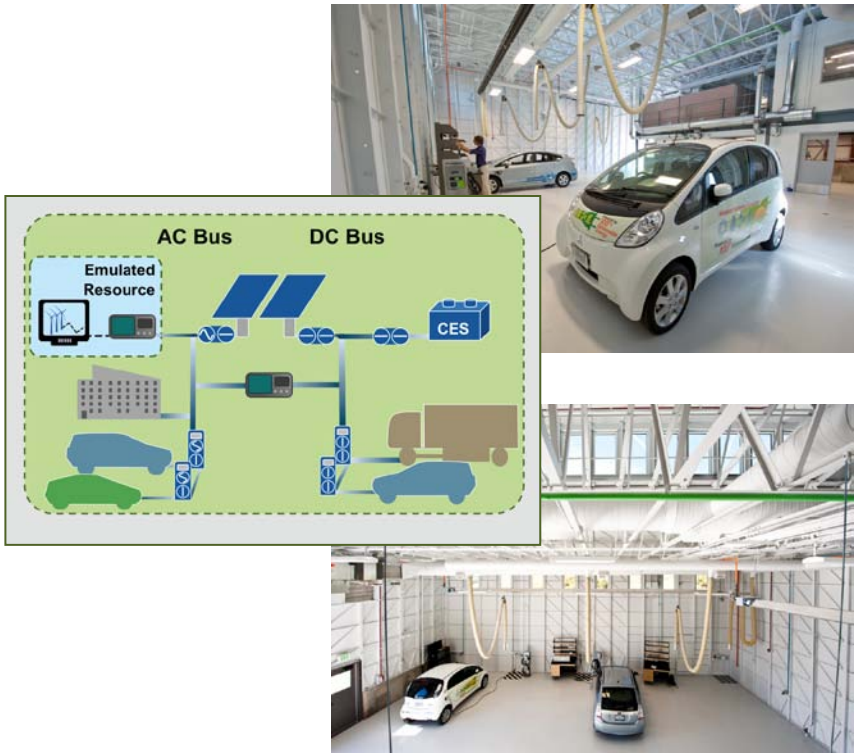

Robust vehicle testing capabilities include a drive-in environmental chamber, which can accommodate commercial-sized hybrid, electric, biodiesel, ethanol, compressed natural gas, and hydrogen fueled vehicles.

SIRFN Subtask 2.4

Microgrids

Desired Level of SIRFN Participation: 3

1 = Low 2 = Med 3 = High

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Description of Activities

NREL's microgrid research and development investigates technologies and methods that enable distributed energy resources to make full-value contributions to the electric grid.

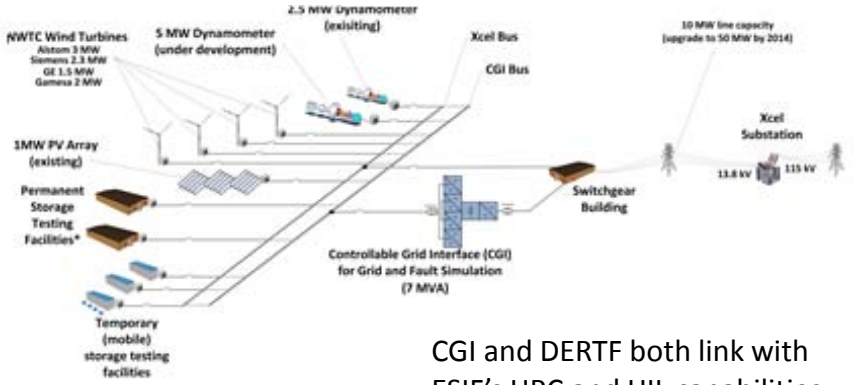
NREL is providing microgrid testing services in compliance with IEEE 1547.1 and 1547.4 standards, including:

- **Performance Testing:** Testing basic operational functions, operating modes and states, and inverter paralleling operation on power inverter, battery, and generators
- **Systems Integration and Transition Testing:** Ensuring systems work together, verifying that key system functions (i.e. picking up the load immediately after the grid disconnects work).
- **Fault Testing:** Testing the fault contribution of the inverter to high and low impedance faults, and the inverter's interaction with typical lateral protection devices.

NREL is currently providing microgrid testing services for the Sacramento Municipal Utility District and Portland General Electric.

Facilities with advanced capabilities to perform microgrid testing include:

- **DERTF -** Testing microgrids up to 200kW; grid simulators, load banks, actual wind turbines and PV systems available
- **ESIF -** Low voltage (600V and under) and medium voltage (15kV and under) test areas; flexible connections for electrical, thermal, and fuel infrastructure
- **CGI at NWTC -** 7MW grid simulation; access to MW scale wind turbines; MV distribution system

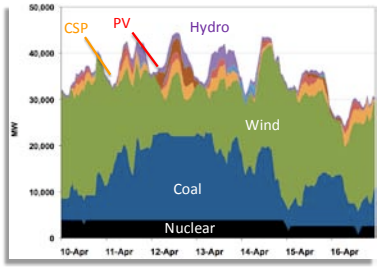


CGI and DERTF both link with ESIF's HPC and HIL capabilities.

Summary of Capabilities Simulation and Testing

Operations Techniques Development

- New systems configurations
- Utility or fuel supply curtailments
- High renewables penetrations
- Extreme weather events
- High storage penetrations
- High demand response deployment
- Resource forecast integration

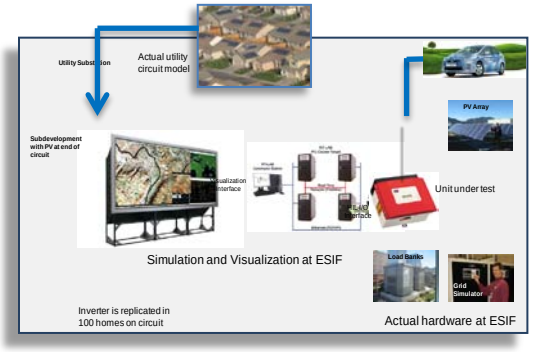


AC and DC sources and infrastructure

A standard interface developed at NREL, the Research Electrical Distribution Bus (REDB), will function as the ultimate power integration "circuit" capable of utilizing multiple AC and DC buses that interconnect laboratories and experiments within the ESIF to test and simulate equipment. Allows for multiple parallel research at MW power level with grid and load simulation.

Power Hardware and Systems-in-the-Loop

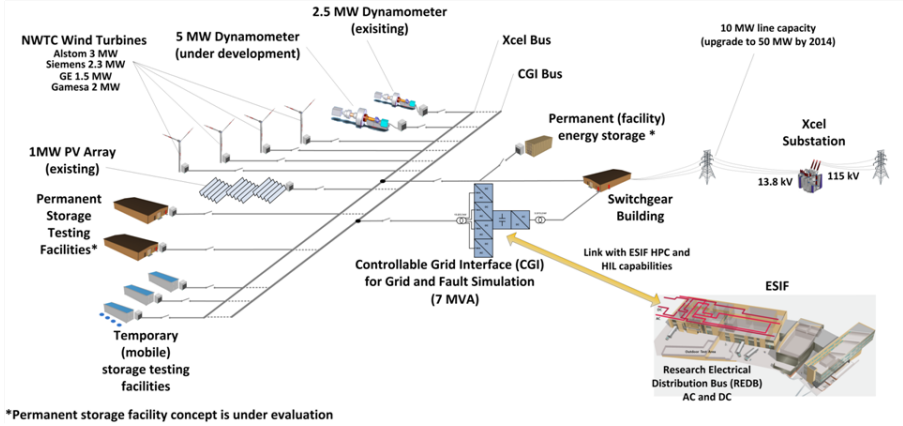
Functioning systems with utility system simulations for real-time, real-power evaluation of high penetration deployment scenarios.



Major Laboratory Equipment

- Hardware-in-the-loop simulator (Opal-RT and RTDS)
- Grid simulator (4x270kW, 690Vac, 400Vdc, DC-800Hz)
- Bidirectional DC supplies (2x250kW, 0-900V)
- PV simulator (multi-module, 0-1000V or +/-500V)
- Research chiller/boiler (750 MBH boiler, 60ton chiller)
- Extensive selection of existing distributed energy systems and high power PV and wind simulation
- Interconnectivity to external field sites for data feeds and model validation

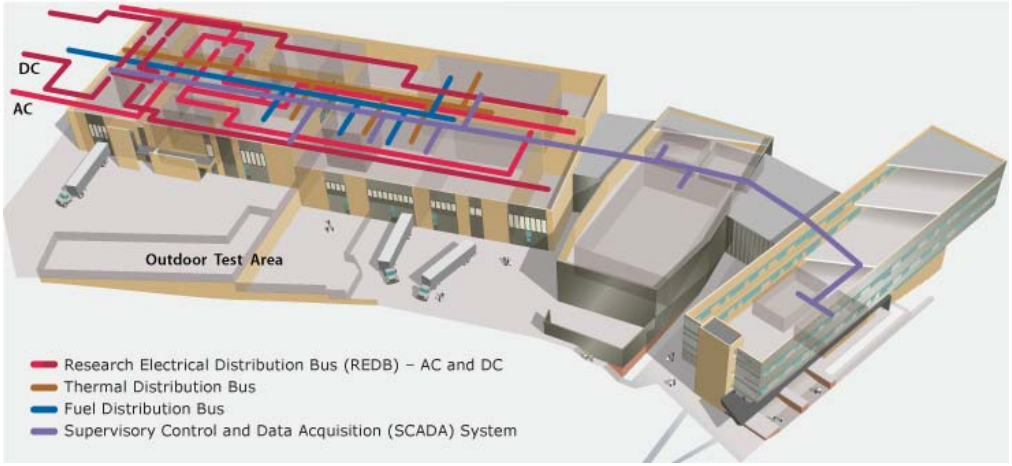
Large-Scale Grid Integration Capabilities



NWTC CGI allows testing of many grid integration aspects for multi-MW utility-scale variable renewable generation and storage technologies.

Summary of Capabilities
Data Acquisition and Analysis

ESIF Data Acquisition : Electricity, Thermal, & Fuel



Fully integrated throughout the ESIF are electrical, thermal, and fuel distribution buses and a monitoring and control system. The monitoring and control system transfers information from experiments being performed in the ESIF labs to a central computer, and researchers and NREL partners can view this data in real time.

Virtual Connections

Supporting labs on the NREL campus are connected to the ESIF's hardware-in-the-loop and high performance computing center.

NREL is also working to make virtual connections between the ESIF and external demonstration sites and large-scale simulation runs. These capabilities will help remote developers complete development in a considerably shorter time frame and by sharing knowledge and expertise across the nation will help to identify optional utility solutions—with greater certainty and confidence—before major capital investments are made.

High-Performance Computing

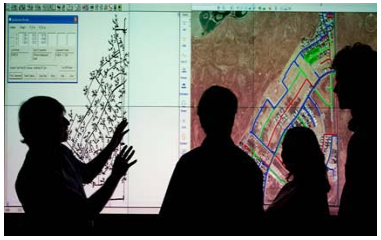
- Petascale computing
- 10,000 sf^2 of uninterrupted, usable machine room space
- The most energy efficient data center in the world dedicated to renewable energy

Visualization & Analysis

State-of-the-art visualization and analytics tools for knowledge discovery in large-scale data, directly supporting both computational and experimental science.

HPC Insight and Collaboration

- *Analytic Visualization* that utilizes interactive visualization techniques as an approach to the analysis of scientific data.
- *Presentation Visualization* that uses visual imagery to illustrate or convey information to visitors and stakeholders.
- 15'X6' 13.8 megapixel rear-projected display wall
- Two-surface stereoscopic immersive virtual environment - 16'x10' wall and 16'x5' floor
- Multiple high-performance researcher workstations



Energy Integration Visualization

- 6 ft. x 23 ft. display wall
- 3D-capable projection system
- 10 projectors w/1080p resolution for a combined resolution of 9600p x 2160p