Energy Systems Integration

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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.
Future Energy Systems are Emerging ...
Grid Integration Issues

- High wind and solar means lesser but *more variable* use of other assets
- High efficiency, demand response, and new loads are changing demand and making it *more variable*
- Existing T&D grid increasingly strained by two-way power flow
- Need *flexibility* in system operations to absorb growing variability
Energy system integration (ESI) = the process of optimizing energy systems across multiple pathways and scales.
ESI RD&D Activities To Date

Solar and Wind
- High Penetration PV integration
- Wind integration with transmission operations

Grid Planning and Operations
- Transmission and Distribution Systems
- Smart Grid Technologies
- Microgrids
- Standards

Energy Storage
- CSP Thermal Storage
- Utility scale batteries
- Distributed storage

Buildings
- Sensors and controls
- Design and integration
- Modeling and simulation
- System integration

Hydrogen and Fuel Cells
- H₂/electric interfaces
- RE electrolyzers
- Storage systems
- Fuel cell integration
- H₂/Grid integration

Advanced Vehicles
- Plug-in-hybrids and vehicle-to-grid integration
- Battery thermal management
- Power electronics

Focus on single devices and small-scale field demos
ESI Goal 1: Integrate Technologies Into System

Characterize and predict how components and devices will interact with the others in the system.
ESI Goal 2: Integrate Across Functional Layers

Characterize and predict how these devices will interact with controls, communications, markets
ESI Goal 3: Integrate Across Physical Scales

Apply this framework to the optimization of existing and future energy systems at a variety of scales
The Energy Systems Integration Facility (ESIF) is NREL’s largest R&D facility (182,500 ft²/20,000 m²), providing space for 200 NREL staff and research partners. The facility includes 15 state-of-the-art hardware laboratories, integrated megawatt-scale electrical, thermal and fuel infrastructure, high performance computation and data analysis capabilities, and 2-D/3-D advanced visualization. For more information, visit [http://www.nrel.gov/esi/esif.html](http://www.nrel.gov/esi/esif.html).
ESIF Integrated Laboratories

Rooftop PV & Wind

Energy Storage Lab
Residential, Community & Grid Battery Storage, Flywheels & Thermal

Smart Power Lab
Buildings & Loads

Energy Systems Integration Lab
Fuel Cells, Electrolyzers

Outdoor Test Area
EVs, Power Transformers

Power Systems Integration Lab
PV Simulator
ESIF Hardware-in-the-Loop Capability

Validation with Field Data

Simulation and Visualization

Hardware Testing

Devices Under Test (e.g. inverter, energy storage, EV, load, etc.)

Scale Up Experiments via HPC

New Specifications for Hardware Development

Visualization Interface

HIL I/O Interface

Load Banks

Grid Simulator

Solar Simulator

Subdevelopment with PV at end of circuit

Utility Substation

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ESIF Linkage to Other Facilities

Enables joint experiments involving both transmission and distribution system elements
A National Network for ESI

ESIF is a key node in the emerging network for ESI research, development, demonstration and analysis
An Opportunity for Leadership

Energy Systems Integration

Complex Systems Modeling

Integrated Data Analytics

Advanced Technologies

Experimental Facilities

Accelerating the Clean Energy Future