NREL
NATIONAL RENEWABLE ENERGY LABORATORY

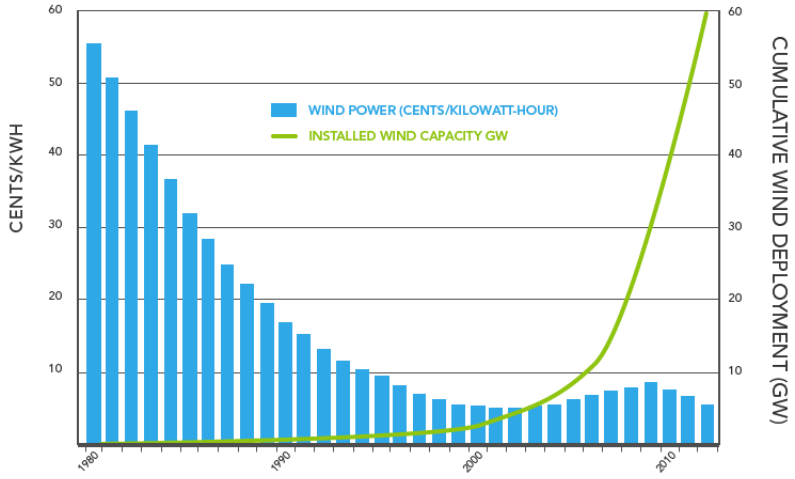
Energy Systems Integration

Dr. Bryan Hannegan
Associate Laboratory Director

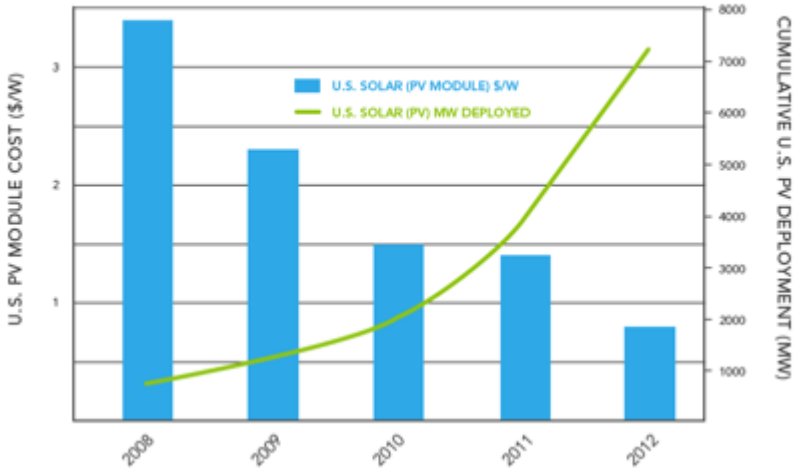
January 2014

Future Energy Systems are Emerging …

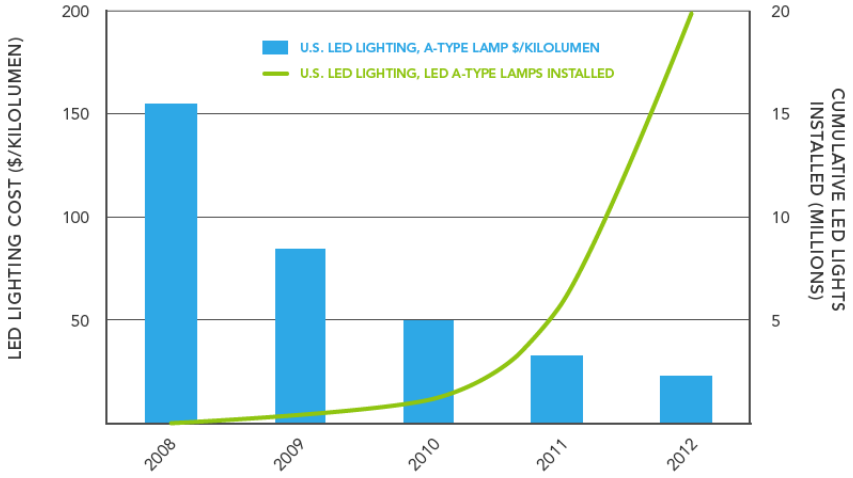
Deployment and Cost for U.S. Land-Based Wind
1980-2012



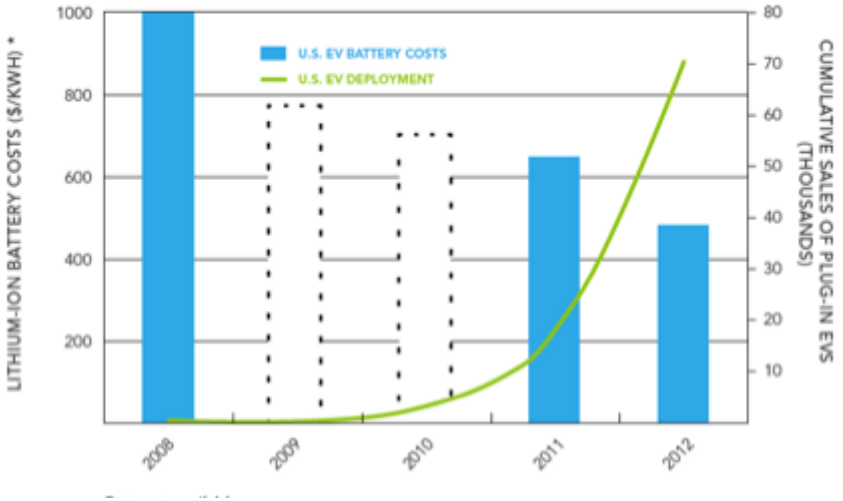
U.S. Deployment and Cost for Solar PV Modules
2008-2012



Deployment and Cost for A-Type LED Lights
2008-2012

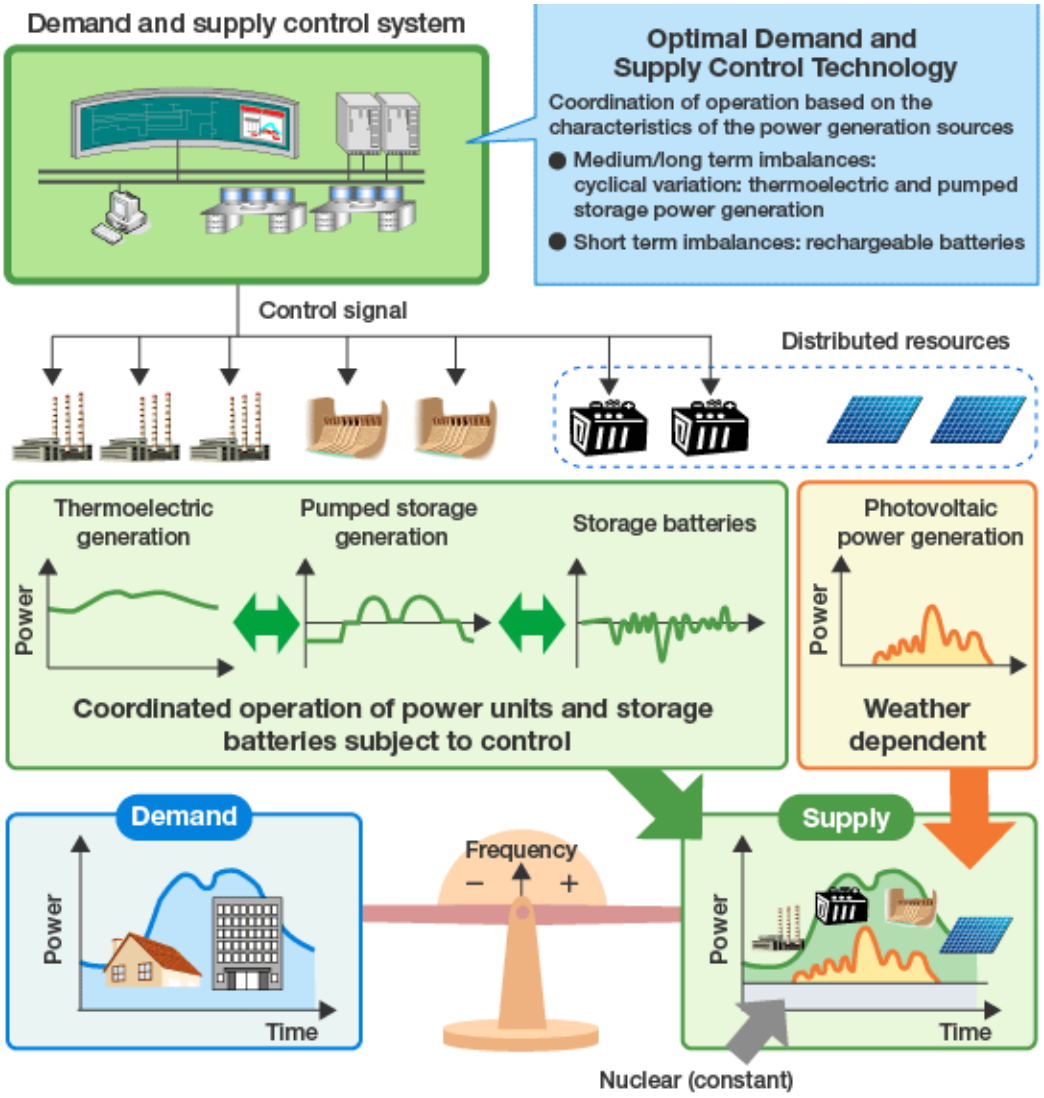


Deployment and Cost for Electric Vehicles and Batteries*
2008-2012



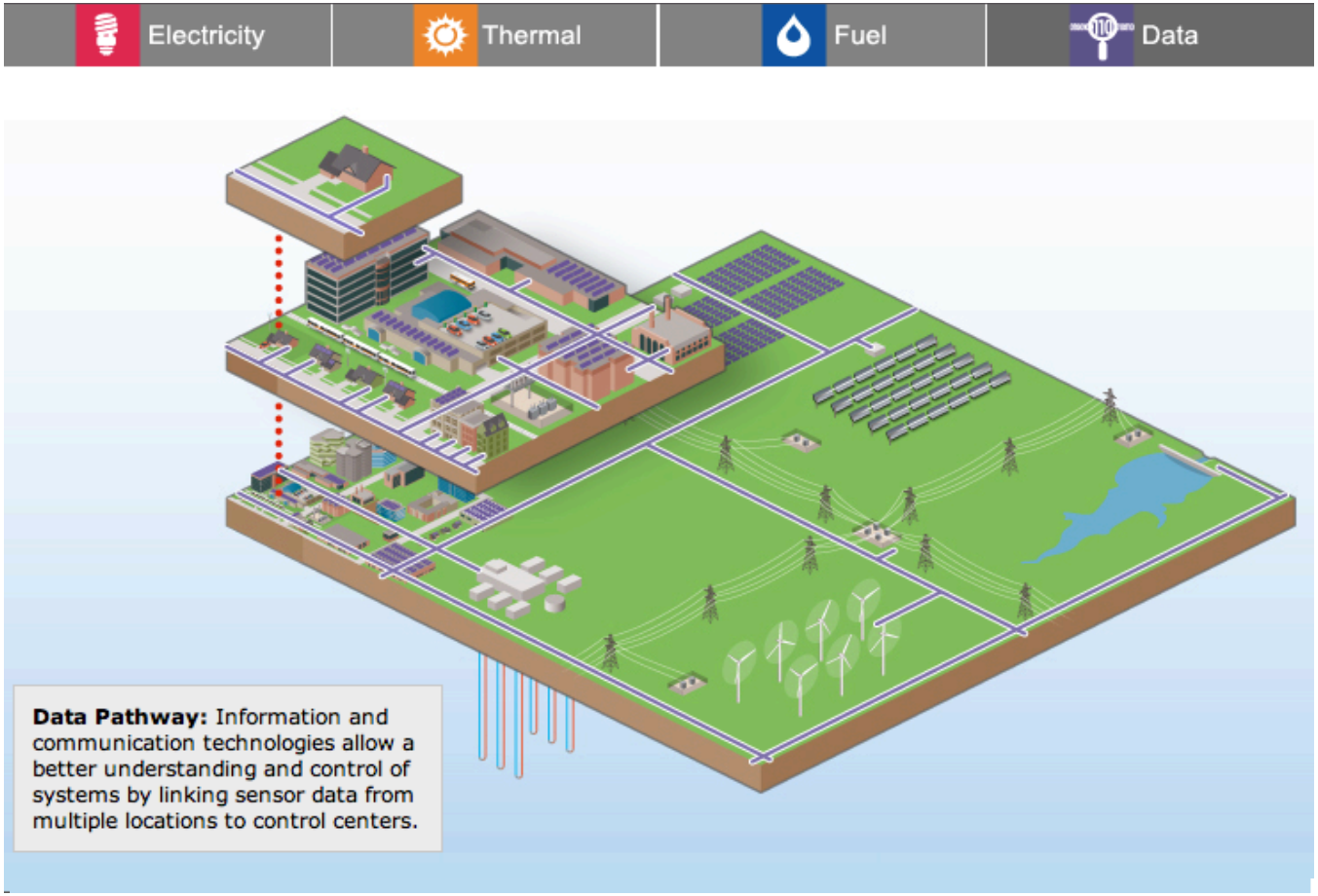
Grid Integration Issues

- 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



New Approach → Energy Systems Integration

Energy system integration (ESI) = the process of optimizing energy systems across multiple pathways and scales



Electricity

Thermal

Fuel

Data

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

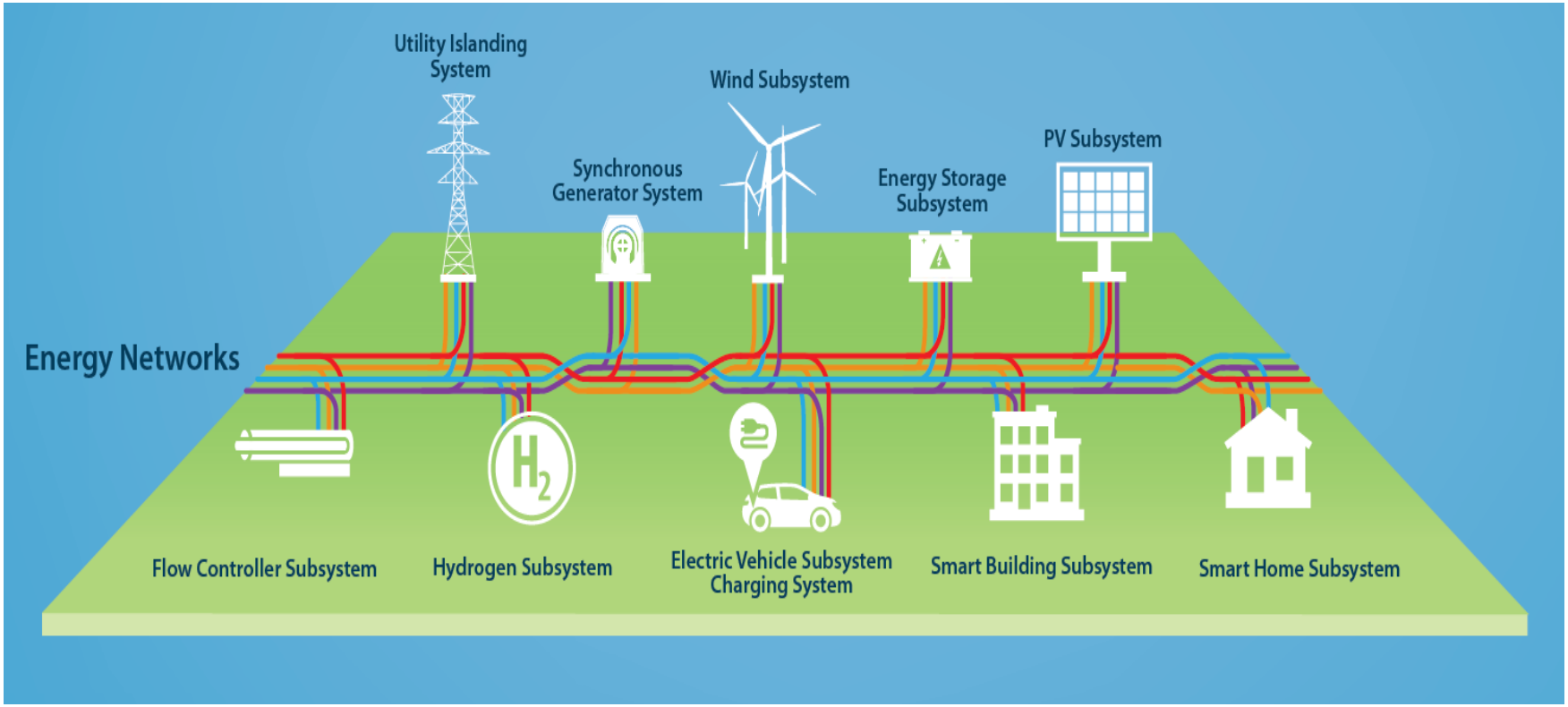
- H_2/electric interfaces
- RE electrolyzers
- Storage systems
- Fuel cell integration
- H2/Grid integration

Advanced Vehicles

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

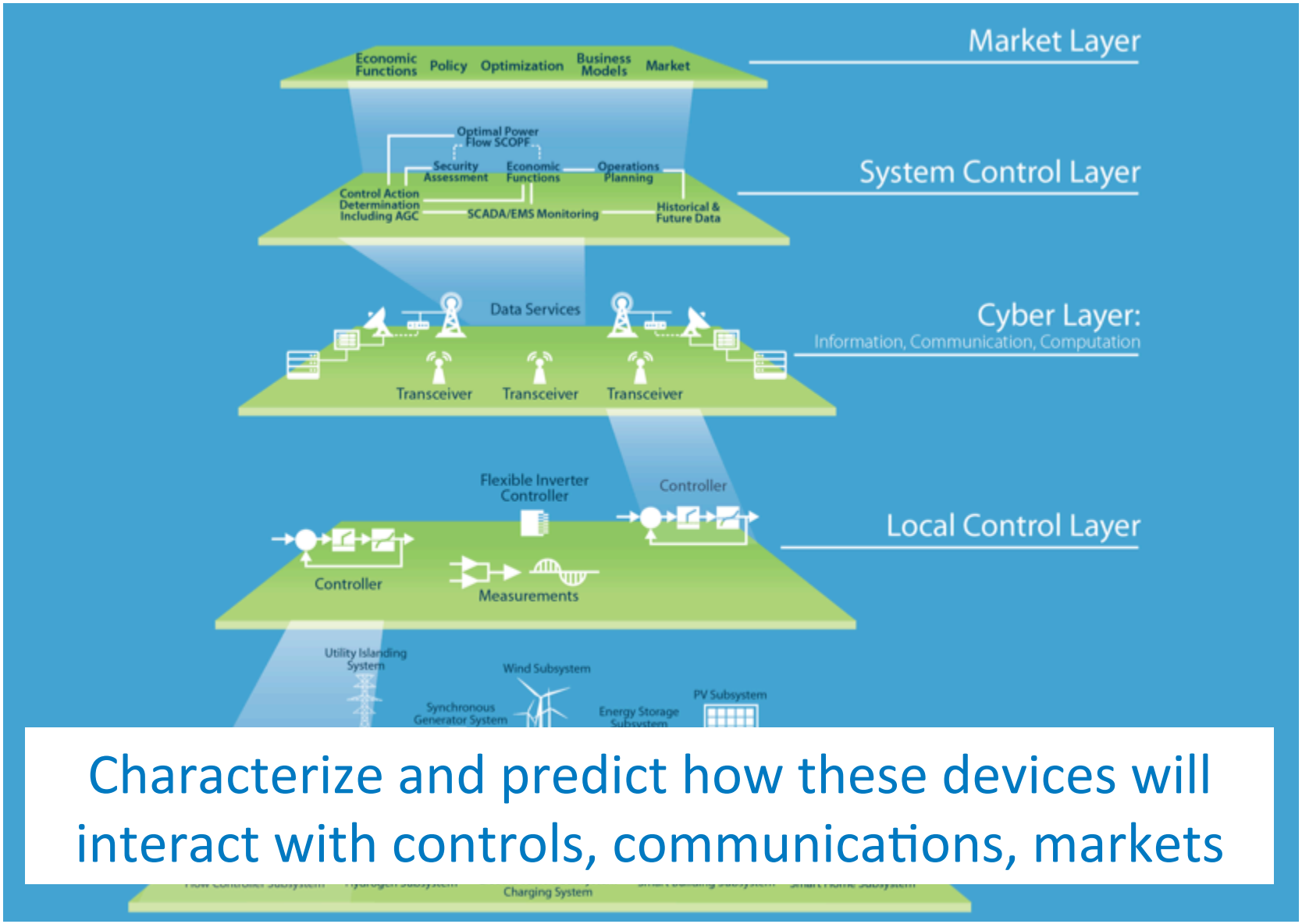
Focus on single devices and small-scale field demos

ESI Goal 1: Integrate Technologies Into System



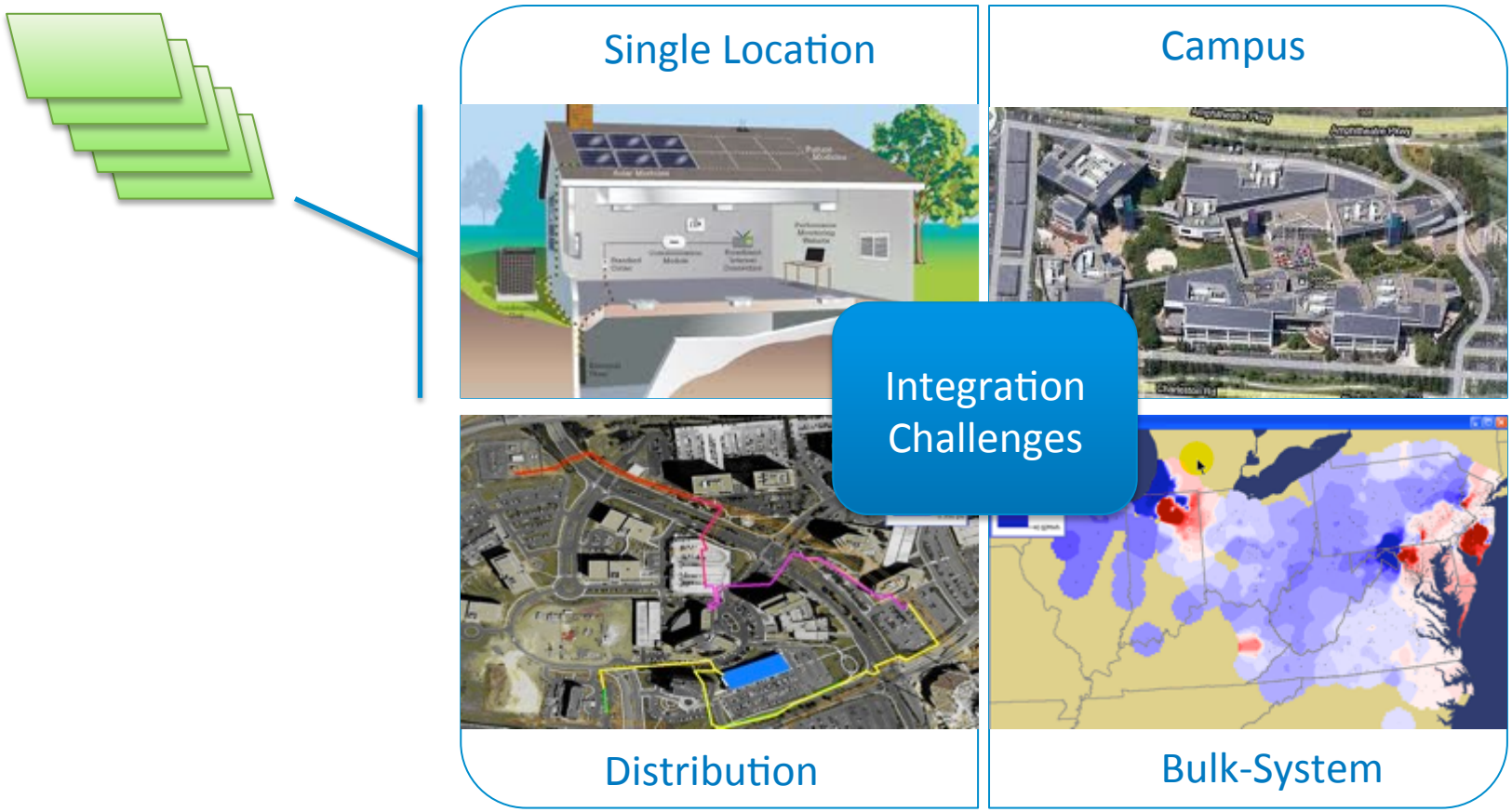
Characterize and predict how components and devices will interact with the others in the system

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



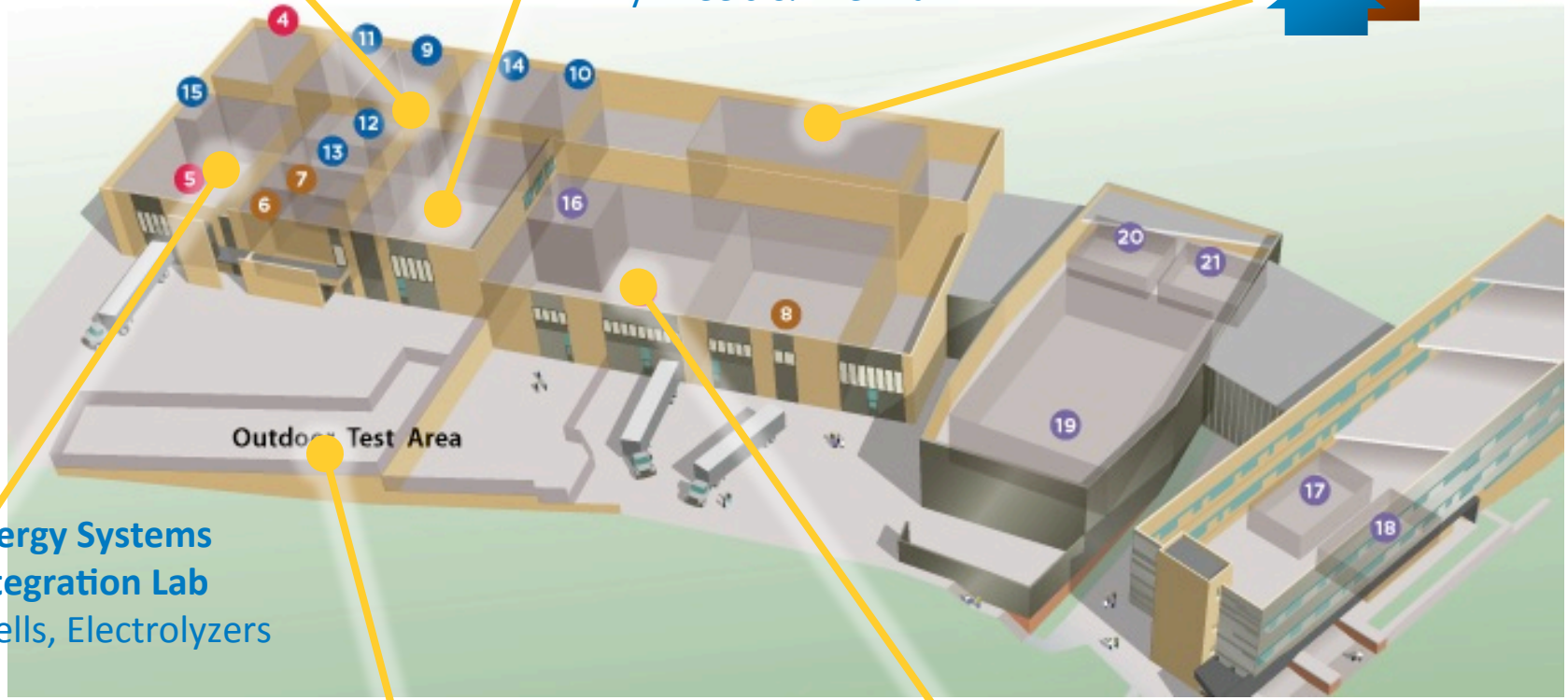
Apply this framework to the optimization of existing and future energy systems at a variety of scales

Energy Systems Integration Facility (ESIF)

- NREL's largest R&D facility (182,500 ft^2 /20,000 m^2)
- Space for 200 NREL staff and research partners
- 15 state-of-the-art hardware laboratories
- Integrated megawatt-scale electrical, thermal and fuel infrastructure
- High performance computation and data analysis capabilities
- 2-D/3-D advanced visualization

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

ESIF Integrated Laboratories



Rooftop PV & Wind

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

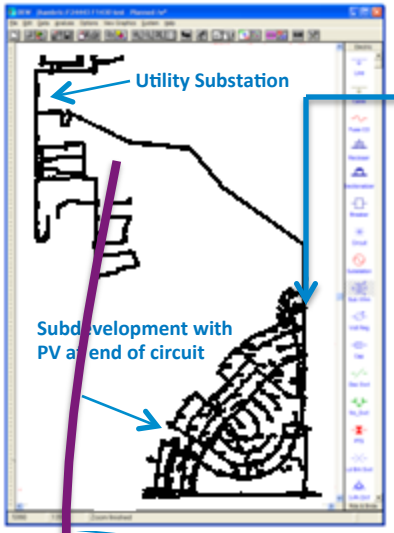
Smart Power Lab
Buildings & Loads

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

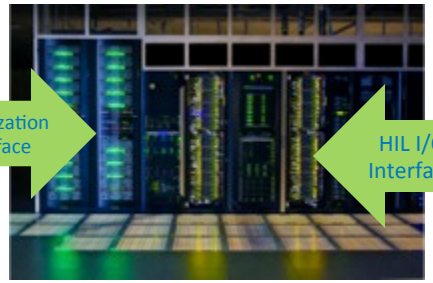


Validation with
Field Data

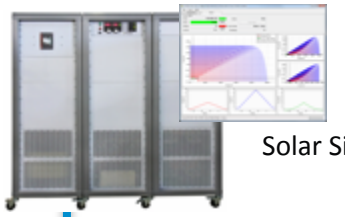
Hardware Testing

Simulation and Visualization

Visualization
Interface



HIL I/O
Interface



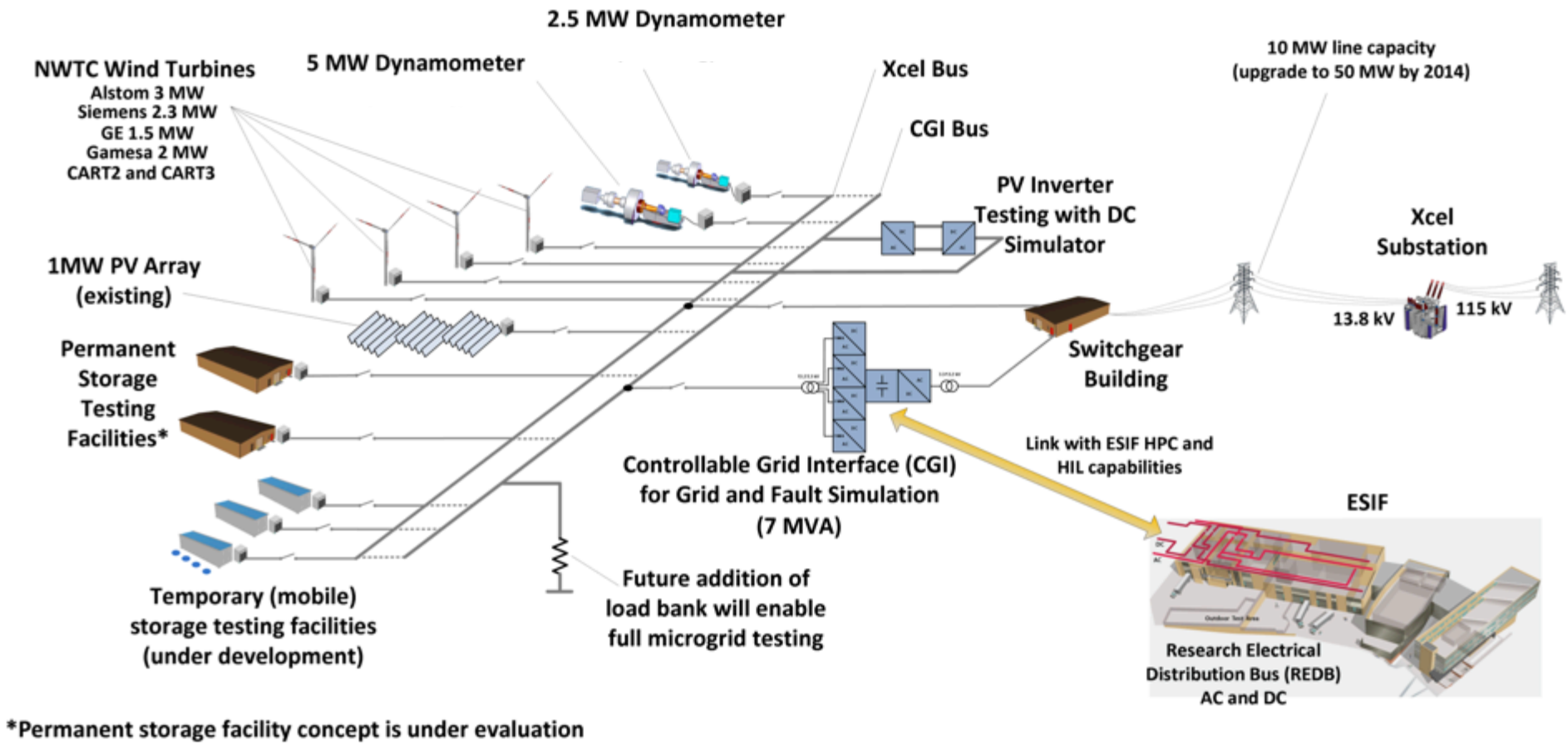
Solar Simulator

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

Scale Up
Experiments via HPC

New Specifications
for Hardware
Development

ESIF Linkage to Other Facilities



*Permanent storage facility concept is under evaluation

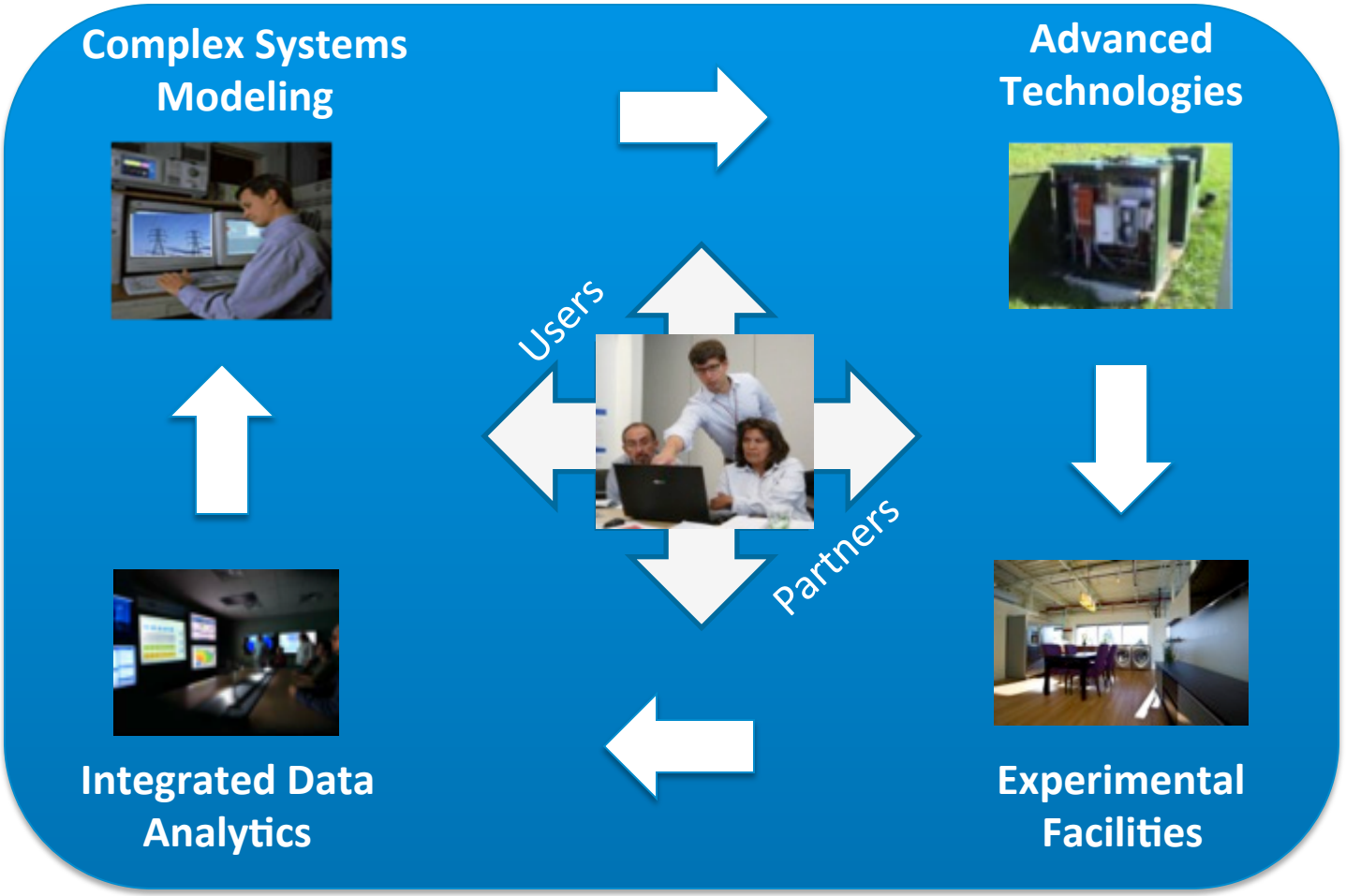
Enables joint experiments involving both transmission and distribution system elements

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



Accelerating the Clean Energy Future