U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Energy Systems Integration

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Grid Modernization: A Holistic Approach

The Grid Tech Team (GTT), with DOE-wide representation, is responsible for leadership within and outside DOE on grid modernization through strategic thinking and improved communication, coordination, and collaboration.

DOE REPRESENTATION

- Office of Science **(SC)**
- Office of Electricity Delivery & Energy Reliability **(OE)**
- Office of Energy Efficiency & Renewable Energy **(EERE)**
- Advanced Research Projects Agency – Energy **(ARPA-E)**
- Chief Financial Office **(CFO)**
- DOE Senior Management **(S1)**

Crosscutting: Grid Modernization

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The Grid Modernization initiative reflects a unified strategy within DOE to address institutional and technological issues and achieve the objective of a more resilient and capable grid system.

Grid Modernization

EERE

- Distributed Energy Resources (with OE)
- Transactive Controls (with OE)
- Forecasting, Stochastic Modeling, Dynamic Reserves (with OE)
- Training in Power Electronics (with OE)

OE

- Distributed Energy Resources
- Transactive Controls
- Energy Management Systems
- Cybersecurity
- Etc.

EPSA

- Framework for Long Term Policy (CI)
- Business Models for the Future
- Modeling and Analytical Tools

Congressional and Intergovernmental Affairs

- Framework for Long-Term Policy (with EPSA)

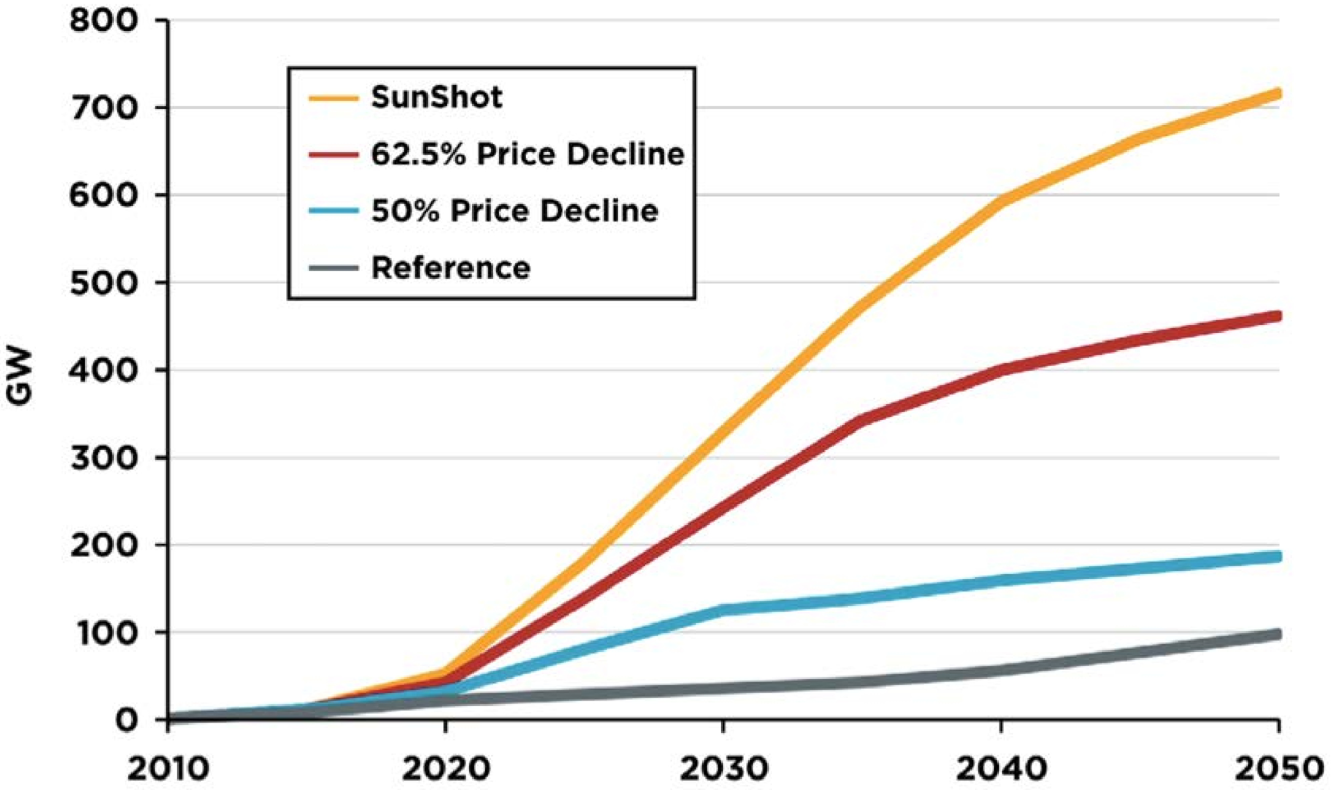
EERE Mission: Focus on Deployment

EERE Mission: The Office of Energy Efficiency and Renewable Energy (EERE) accelerates development and ***facilitates deployment of energy efficiency and renewable energy technologies* and market-based solutions** that strengthen U.S. energy security, environmental quality, and economic vitality.

- Integration of EE and RE technologies into the grid at scale is a major challenge facing deployment, especially for wind, solar, and vehicles. EERE must address this challenge to fulfill its mission.

SunShot: Price Decreases May Lead to Deployment at Scale

As hardware prices continue to fall and technologies like solar become more accessible, addressing the deployment challenges associated with scale become increasingly important.



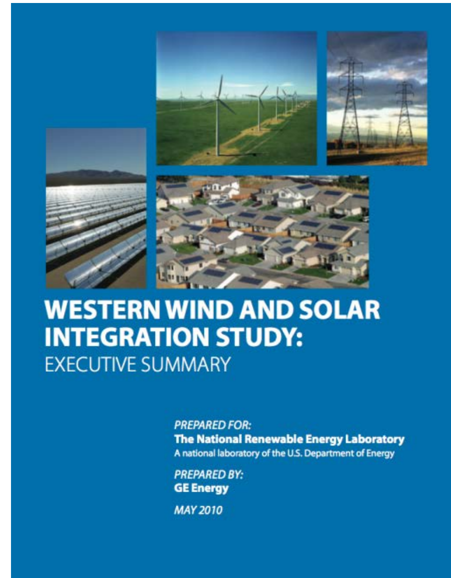
EERE Leadership: Moving Beyond Conventional Wisdom

The vision and leadership within EERE has been a driving force in moving beyond the limits of conventional wisdom in terms of integrating EE and RE technologies into the grid at scale.

- Renewable Energy Futures Study (80% by 2050)
- Wind Vision Study: 20% Wind by 2030
- Solar Vision Study: 14% Solar by 2030
- Renewable Systems Integration (2008)

EERE: Vision and Leadership

- Renewable Energy Futures Study: 80% by 2050
- More than 50% from wind and solar



Renewable Energy Futures

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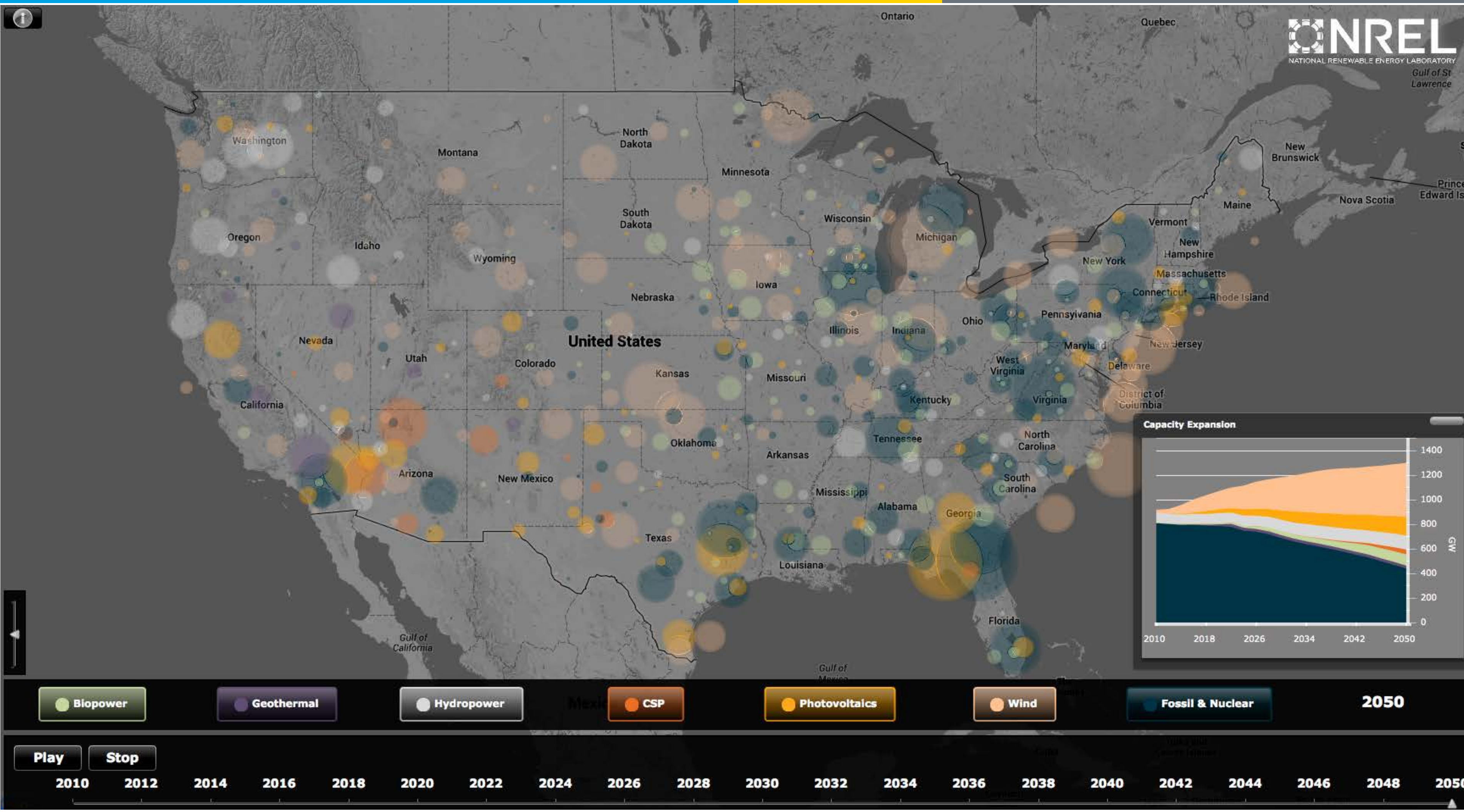


http://www.nrel.gov/analysis/re_futures/

EERE Energy Systems Integration

Vision

- EE and RE technologies are integrated into the energy system in a safe, reliable, and cost effective manner at a relevant scale to support the nation's goals of 80% clean electricity by 2035 and reducing oil imports by 33% by 2025.

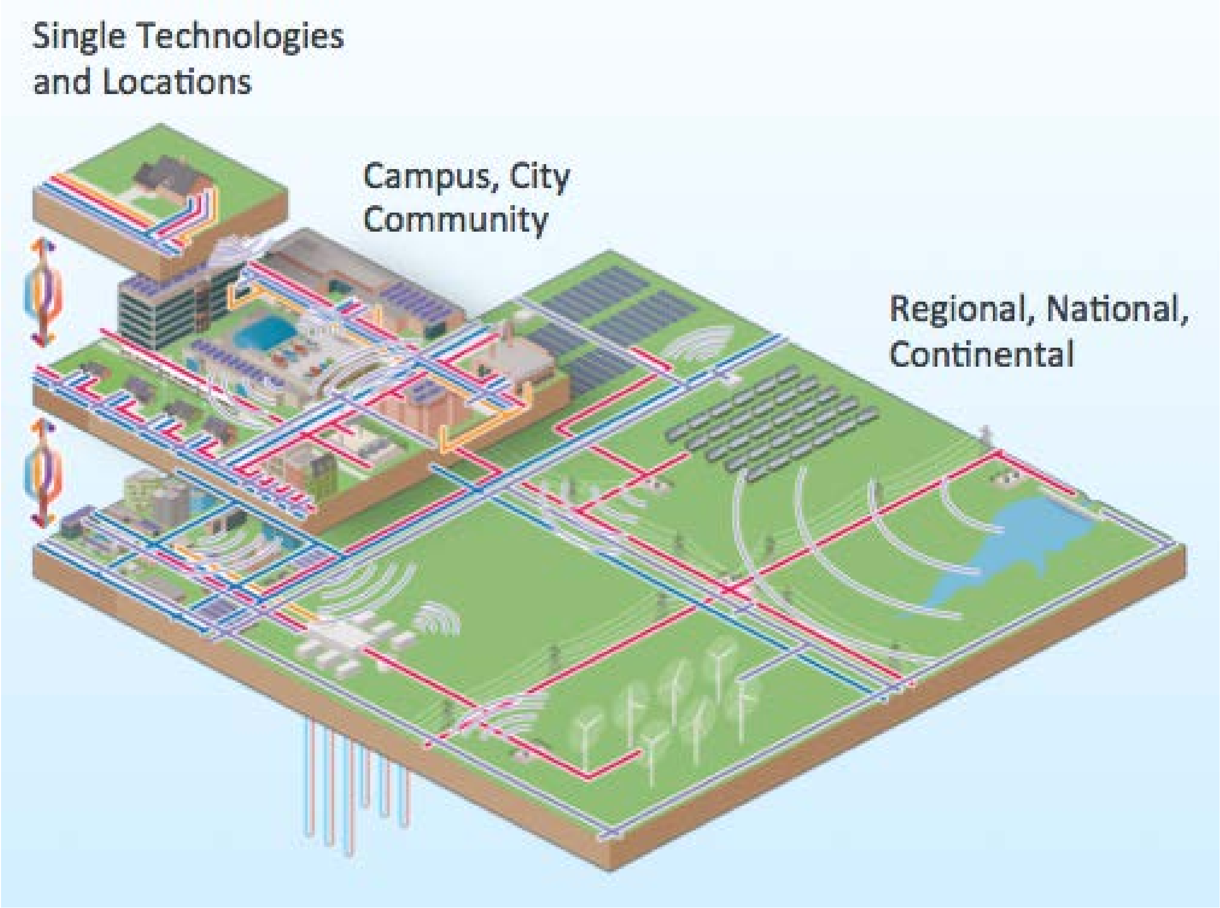
Mission

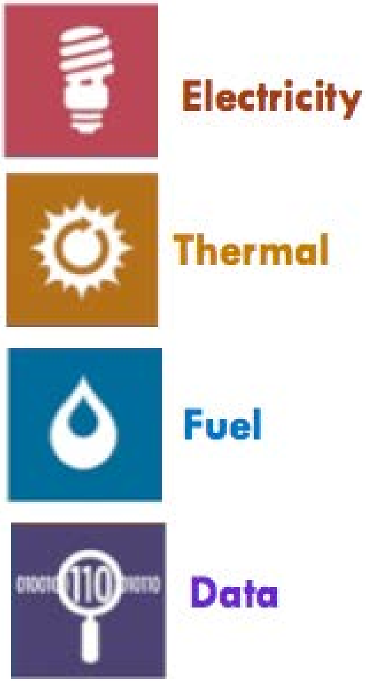
- Conduct high impact RD&D necessary to enable the integration of energy efficiency and renewable energy technologies into the energy system at a scale necessary to realize our vision.

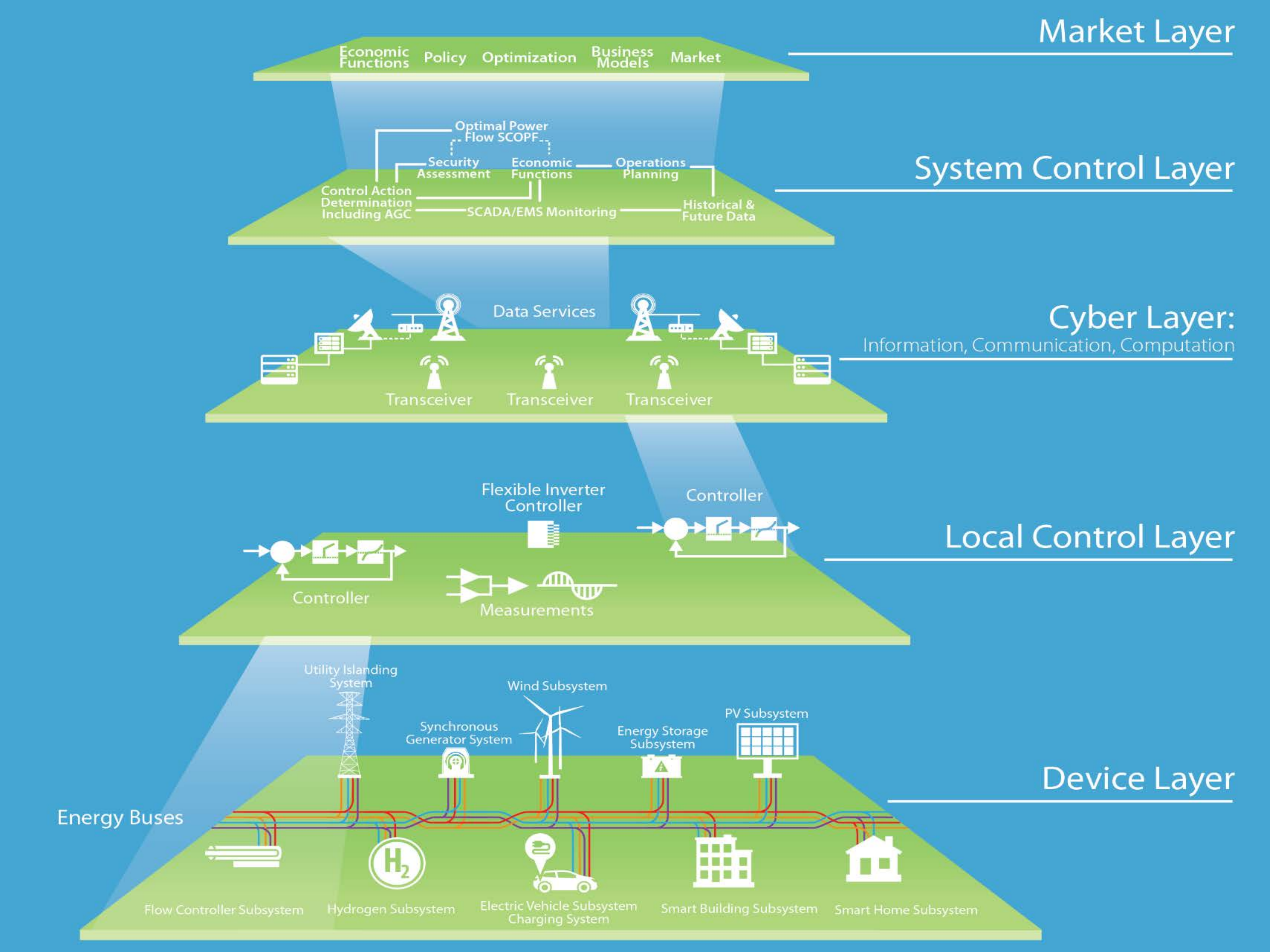
Understanding the holistic impacts of integrating solar, wind, vehicles, and buildings on the grid is critical.

Energy Systems Integration – The Concept

ESI Vision: Highly integrated, flexible, and efficient systems that enable utilization of clean energy sources while maintaining reliability at an affordable cost






Market Layer
Economic Functions
Policy
Optimization
Business Models
Market
System Control Layer
Optimal Power Flow SCOPF
Security Assessment
Economic Functions
Operations Planning
Control Action Determination Including AGC
SCADA/EMS Monitoring
Historical & Future Data
Cyber Layer:
Information, Communication, Computation
Data Services
Transceiver
Transceiver
Transceiver
Local Control Layer
Flexible Inverter Controller
Controller
Controller
Measurements
Device Layer
Utility Islanding System
Wind Subsystem
Synchronous Generator System
Energy Storage Subsystem
PV Subsystem
Energy Buses
Flow Controller Subsystem
Hydrogen Subsystem
Electric Vehicle Subsystem Charging System
Smart Building Subsystem
Smart Home Subsystem

EERE Challenges in Energy Systems Integration

To enable this improved integration, EERE will address the following **four key challenges** over the next 5 years:

1. Develop advanced components, controls, communications and information technology that reduce the barriers to the adoption of new energy efficiency and renewable energy technologies connected to the grid.

2. Deliver high-fidelity, real-time forecasts, models and simulations to support optimized design, planning, and operations of energy systems with high penetrations of energy efficiency and renewable energy technologies.

3. Deliver credible analyses that enable policy, markets, and business model transformation to support deployment of high levels of energy efficiency and renewable energy technologies.

4. Enable full-scale deployment of energy efficiency and renewable energy systems at high penetrations that provide comparable or superior reliability, resilience, and affordability relative to today's systems.

Challenges Associated with Integrating EERE Technologies into the Grid at Scale

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Distribution

Technical ↔ **Institutional**

Transmission

Distribution: Technical Challenges

- Voltage variation
- Unintentional islanding
- Protection coordination
- Two-way power flow
- Car Charging

Distribution Institutional

- New utility business models
- New interconnection standards

Transmission: Technical Challenges

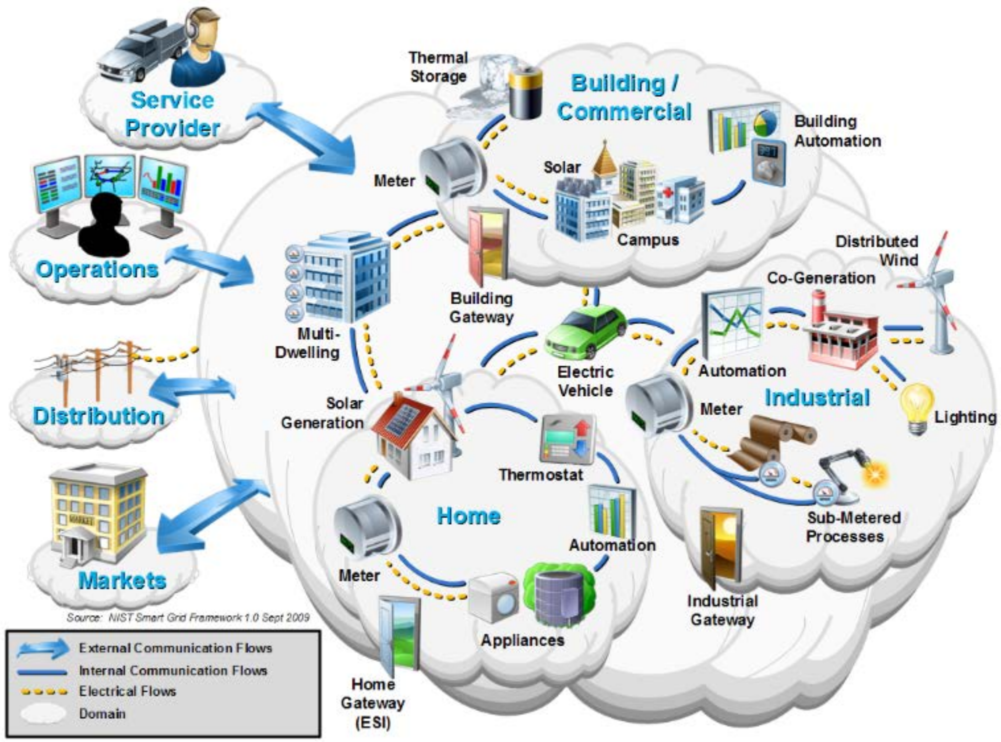
- Variability and uncertainty in generation
- Reliability
- Integrated Resource Planning

Transmission: Institutional Challenges

- New NERC and FERC standards
- Development of new markets (capacity)
- Cost allocation

EERE ESI Vision

- Distributed generation (e.g., rooftop PV, fuel cells, combined heat and power), electric vehicles, building technologies, energy storage, and demand response are being deployed and utilized on distribution systems. Integration of these technologies and understanding of their impact on the grid have been studied independently without consideration of how various technologies may impact one another. A comprehensive approach to distributed energy resources integration will help identify synergies, improve technology interoperability, and increase system efficiency.



Understanding the holistic impacts of integrating solar, wind, vehicles, and buildings on the grid is critical.

Distributed Energy Resources Integration

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Solar

- Voltage Control
- Protection and Restoration
- Systems Optimization
- Sensors and Data
- Value Proposition

Buildings

- Standardization of Data
- High Resolution Data
- Data Analytics/Tools
- Sensors
- Open Architecture Building Energy Controls Systems

DER Integration

Vehicles

- Grid System Analysis Tools
- End-to-End Communications and Controls
- Interoperability Standards
- Value Proposition

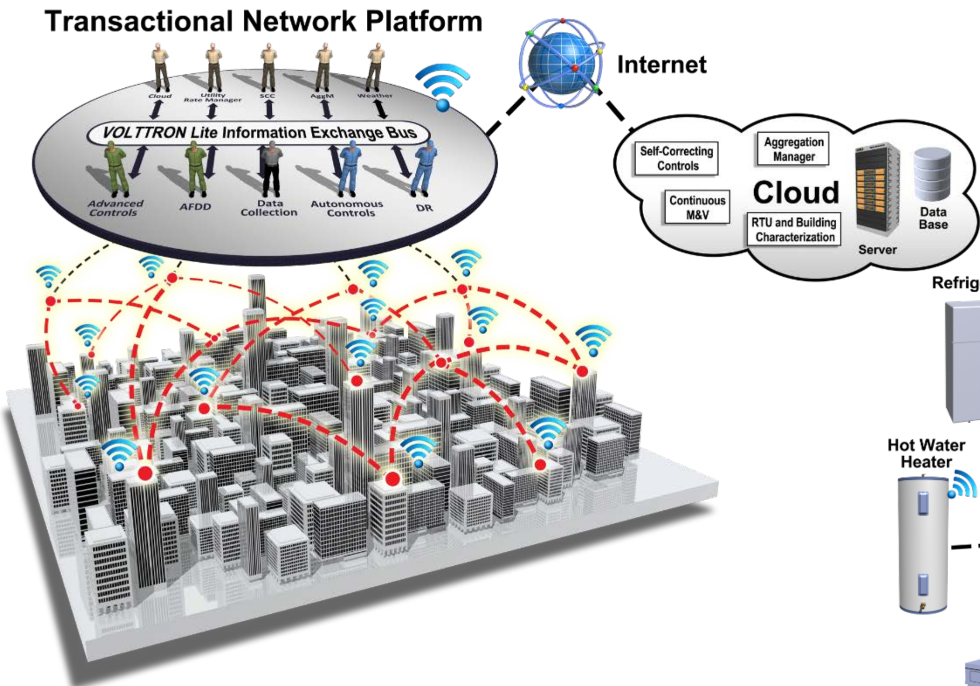
OE

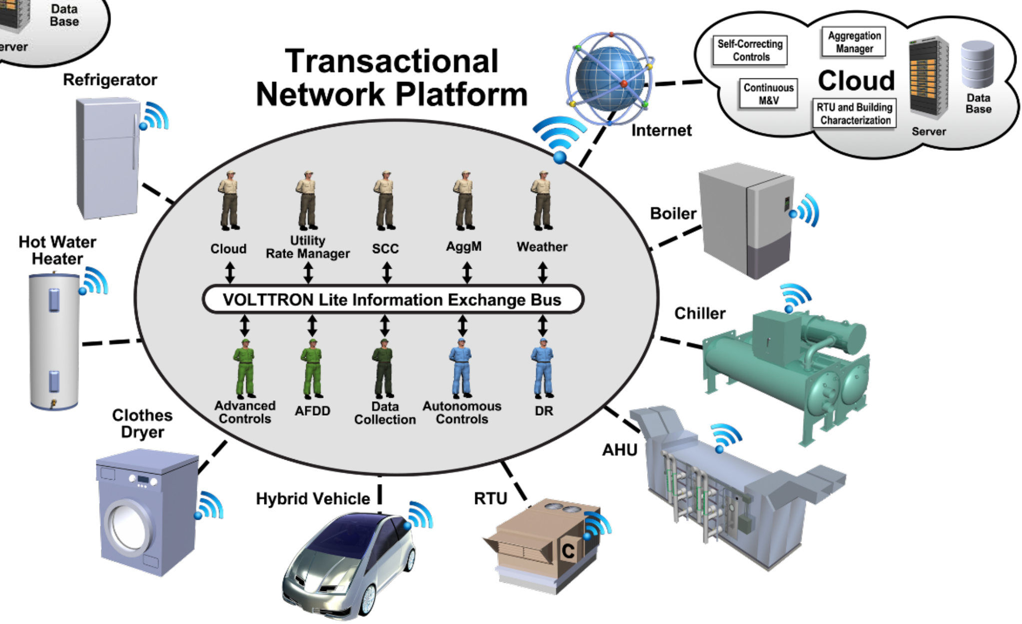
- Supporting development of standards and protocols, such as the Smart Grid Interoperability Panel (SGIP), for the interoperability of components, devices, and systems;
- Interface with building management systems;
- Synergies between DER's;
- Exploring AC/DC distribution circuit architectures to increase energy efficiency; and
- Developing technology models and simulators to study interactions between technologies.

Transactive Controls

Transaction based controls are control solutions that allow operational decisions to be based on market signals (i.e. commodity, service, retrofits, etc.) whether it is…

- A direct indicator (i.e. time of day electricity price) or
- An indirect indicator (i.e. price given the fuel and carbon impact of the existing electricity mix). .





Transactive Controls:

Buildings Technology Office

- Developing the fundamental economic and control theories needed to support transactive and transaction based control in singular and groups of equipment by class;
- Advancing sensor and controls to communicate and respond to outside signals by secure, reliable and robust means;
- Establishing the communication, measurement, and verification requirements processes; and
- Conducting demonstrations to assess the feasibility, merits and implementation protocols for transactive energy systems.

Office of Electricity

- Developing the fundamental economic and control theories needed to support transactive control;
- Determining the quantitative, locational, and temporal value of energy and services for distribution systems;
- Advancing stochastic models and tools to simulate the impacts of transactive control;
- Exploring the impact of feeder designs and architectures on the value of energy and services;
- Establishing the communication, measurement, and verification requirements needed; and
- Conducting demonstration to assess the merits and feasibility of transactive control

EERE: Energy Systems Integration by Technology Office

Solar Energy Technologies Office

- Behind the meter storage
- Increase penetration of solar technologies using new interconnection standards

Wind and Water Energy Technology Office

- Wind Integration Studies
- Power System Flexibility Analysis
- Grid Operations Analysis
- Pumped Storage Hydropower feasibility and economic analysis

Vehicles Technologies Office

- Support the development of codes and standards related to the interoperability of PEV's
- Evaluation of data collection from EV charging infrastructure

Hydrogen and Fuel Cell Technologies

- Primary activities include inverter testing, electrolyzer validation and potentially stationary fuel cells

Buildings Technologies

- Investigation of transactive controls and interoperability in building loads

Solar Energy Grid Integration Systems – Advanced Concepts (SEGIS-AC)

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Objectives

- Reduce overall PV costs
- Allow high penetration
- Enhance performance

Awards

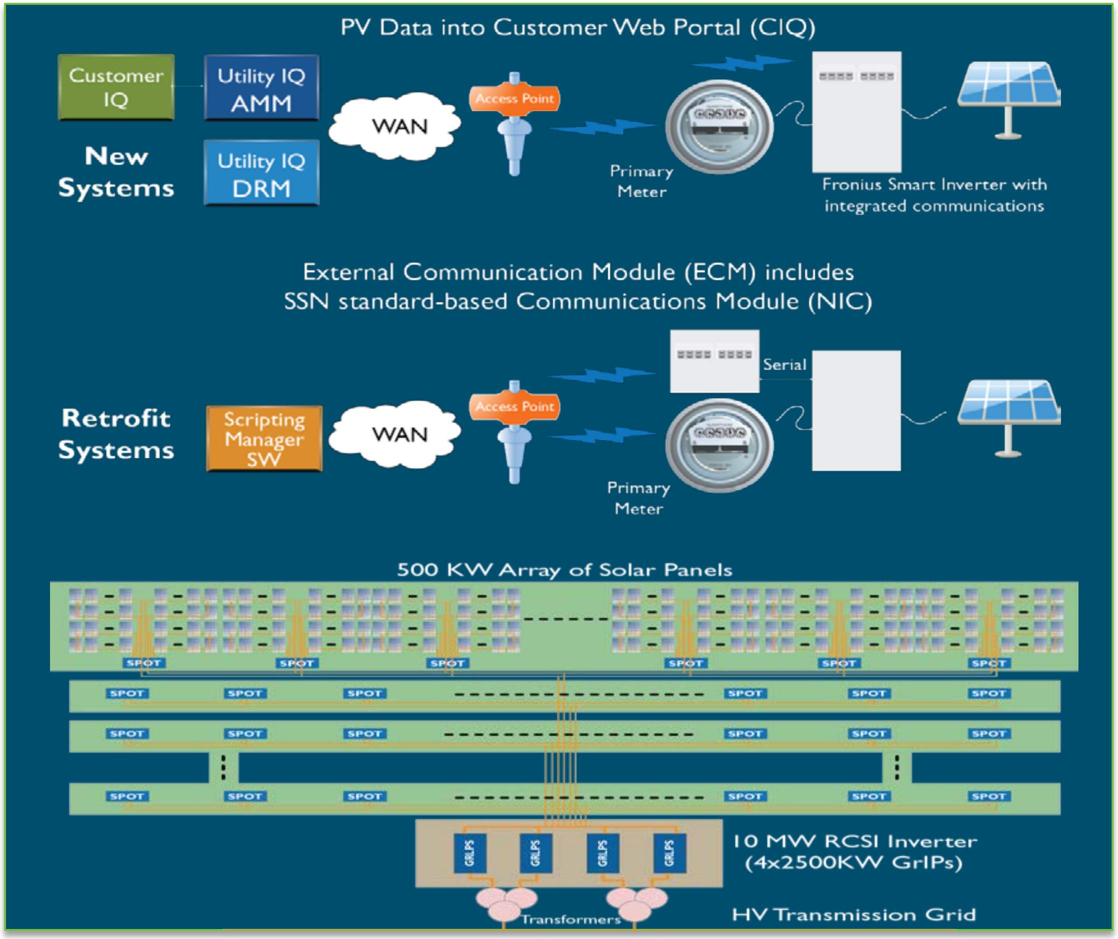
Eight projects; three years; $25.9 million:

Topic 1: Smart-Grid Functionality

- **University of Hawaii** ($6,100,000) – Residential scale
- **EPRI** ($4,400,000) – Utility scale demo
- **Advanced Energy** ($3,100,000) – PMU-based control
- **Satcon** ($3,000,000) – Automatic voltage control

Topic 2: Reducing Costs

- **SolarBridge** ($2,300,000) – Microinverter
- **General Electric** ($2,100,000) – Plug-and-play
- **Alencon** ($3,000,000) – MW inverter
- **Delphi** ($1,900,000) – kW inverter



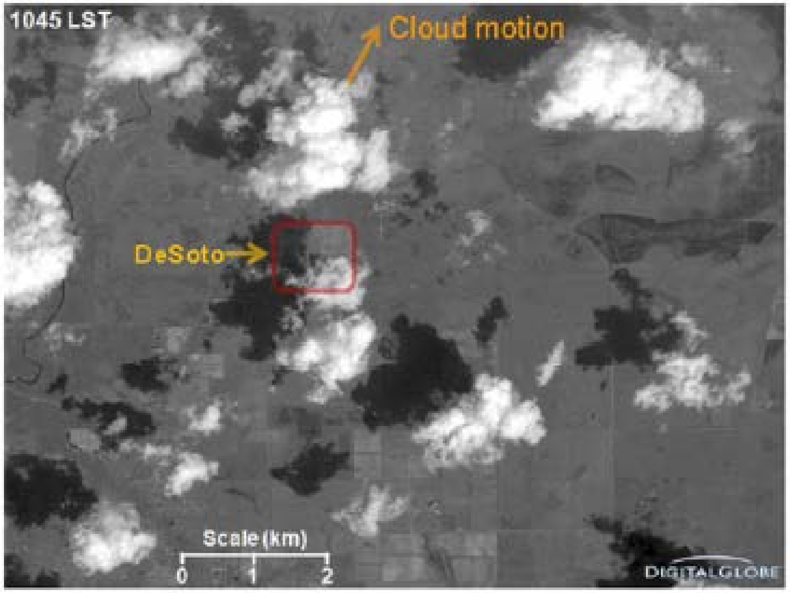
Solar Resource Forecasting

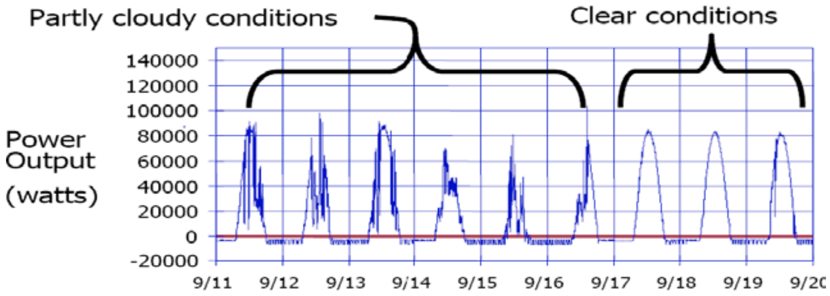
Objectives:

- Improve accuracy of solar resource forecasts
- Enable widespread use of solar forecasts in power system operations

Impacts:

- Increase dependability of power output prediction
- Prepare for impending intermittencies to minimize grid impacts





Focus Areas:

1) Develop Standardized Metrics & Target Values
2) Develop Innovative algorithms and validate
3) Demonstrate value with utilities/system operators

Key Actions:

1) RFI and Workshop conducted
2) Solar Forecasting FOA issued (3 year, $ 9 MM)
3) Evaluating Applications – close to selection

2011 $000K

2012 $4.5M

2013 $4.5M

2014 $000

Wind Forecast Improvement Project

WWPP – Joel Cline

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Project Topic, Summary & Goals

WFIP is a DOE sponsored research project that aims to improve the skill of NOAA's short-term weather forecast models at predicting foundational weather parameters (for example, wind speed, turbulence intensity, and icing conditions) that impact wind energy generation. WFIP participants include several DOE and NOAA research laboratories, the National Weather Service, and partners from the private sector.

Current Status & Findings

Initial analysis showing marked improvements to 0-6 hour forecast. Analysis phase October 1, 2012- July 31, 2013.

Lab/Organization

NOAA

PI: Jim Wilczak

Stan Benjamin

Melinda Marquis

Jeff Freedman

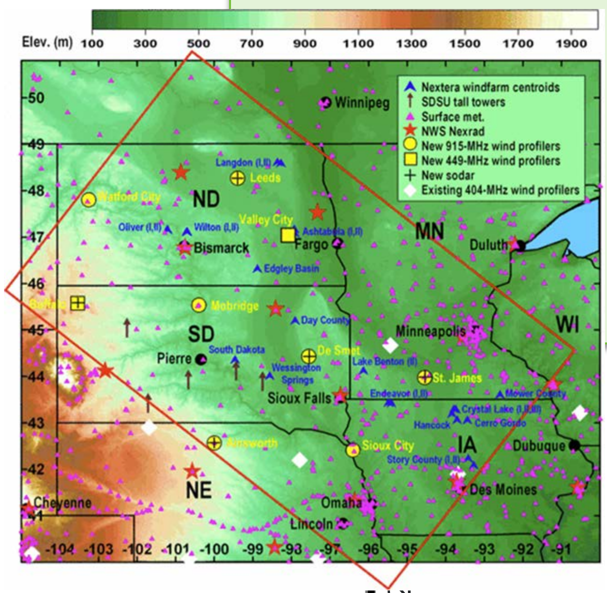
Cathy Finley

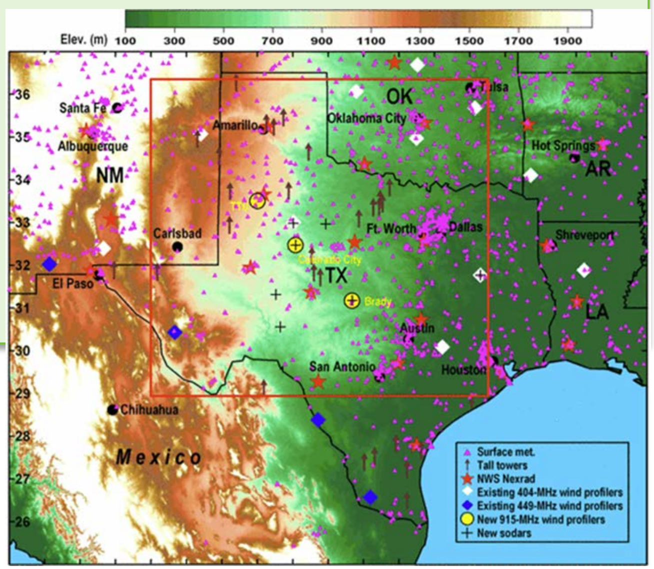
Key Collaborators

NOAA/ OAR – ESRL & NCEP

WindLogics Inc.

AWS Truepower





2010	$2.0 M
2011	$3.075M
2012	$750K
2013	$400K

Western Wind and Solar Integration Study 2

WWPP – Charlton Clark

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Project Topic, Summary & Goals

The goal of the Western Wind and Solar Integration Study Phase 2 (WWSIS2) is to determine the wear-and-tear costs and emission impacts of wind- and solar-induced cycling and ramping of the thermal fleet. It will also compare the impacts of wind versus solar on the grid and examine sub-hourly impacts and economic dispatch. Finally, it will investigate mitigation options including the cost-benefit analysis of upgrading or retrofitting existing coal- and gas-fired generators for flexibility. WWSIS2 is cost shared between Wind, OE, and Solar. WECC is cost-sharing the APTECH subcontract.

Lab/Organization

NREL

PI: Debra Lew

Key Collaborators

WECC, APTECH, GE, Wind Wear, REPPAE

Current Status & Findings

- Calculated wear-and-tear costs and emissions impacts from cycling and ramping for several types of thermal generators.
- Calculated ceiling for wear-and-tear costs and emissions impacts, finding changes to benefits of renewables of up to a few percent.
- Revised wind data and forecasts.
- Created 4 scenarios including three 33% renewables scenarios and built transmission for each scenario using iterative load flows.
- Currently running 4 scenarios in production simulation model.
- Presented findings at IEEE PES, Windpower, NRECA AREGC, UVIG, and other forums.