NREL
NATIONAL RENEWABLE ENERGY LABORATORY





Integrating Solar into a Modernized Grid

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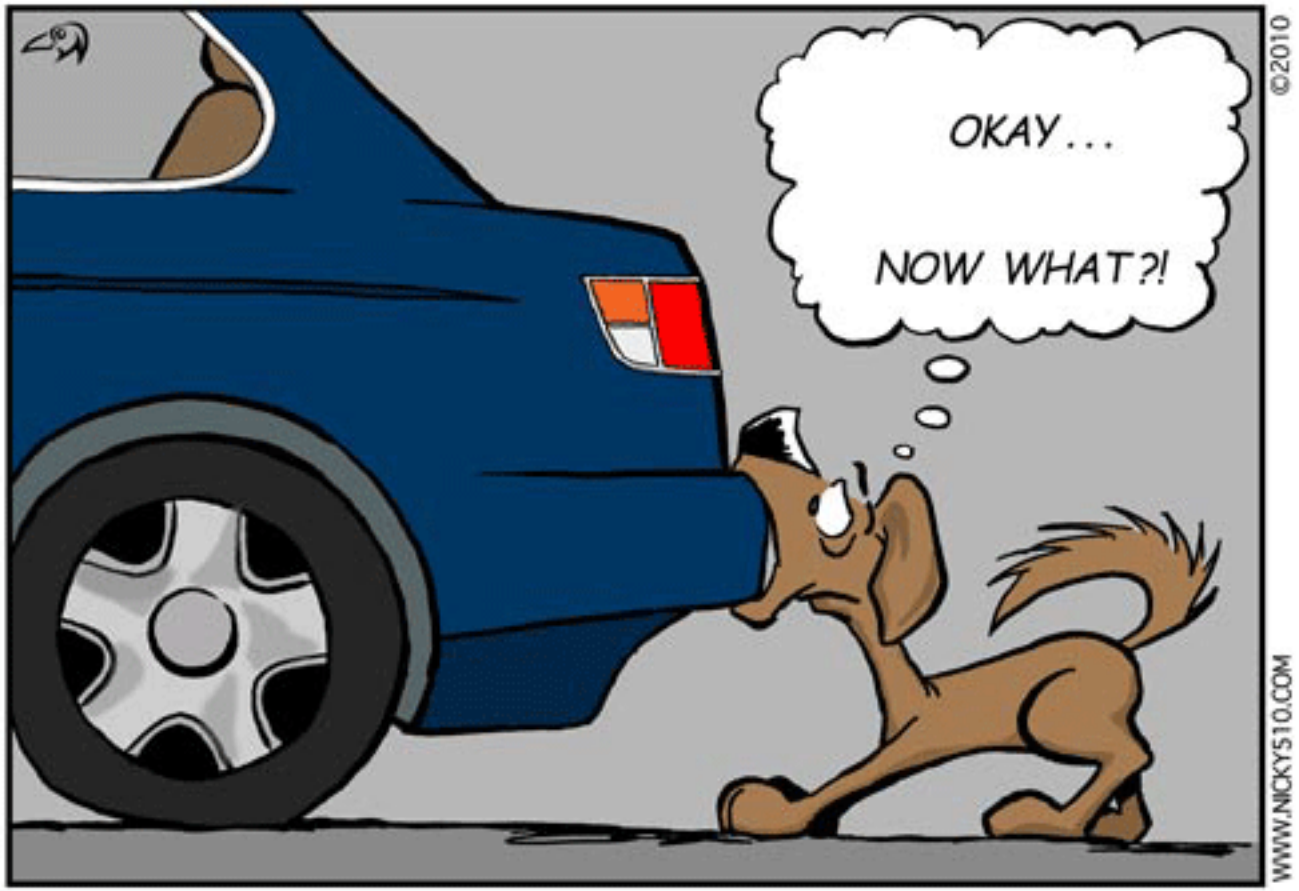
Midwestern Governors' Association
November 15, 2016


OKAY...
NOW WHAT?!
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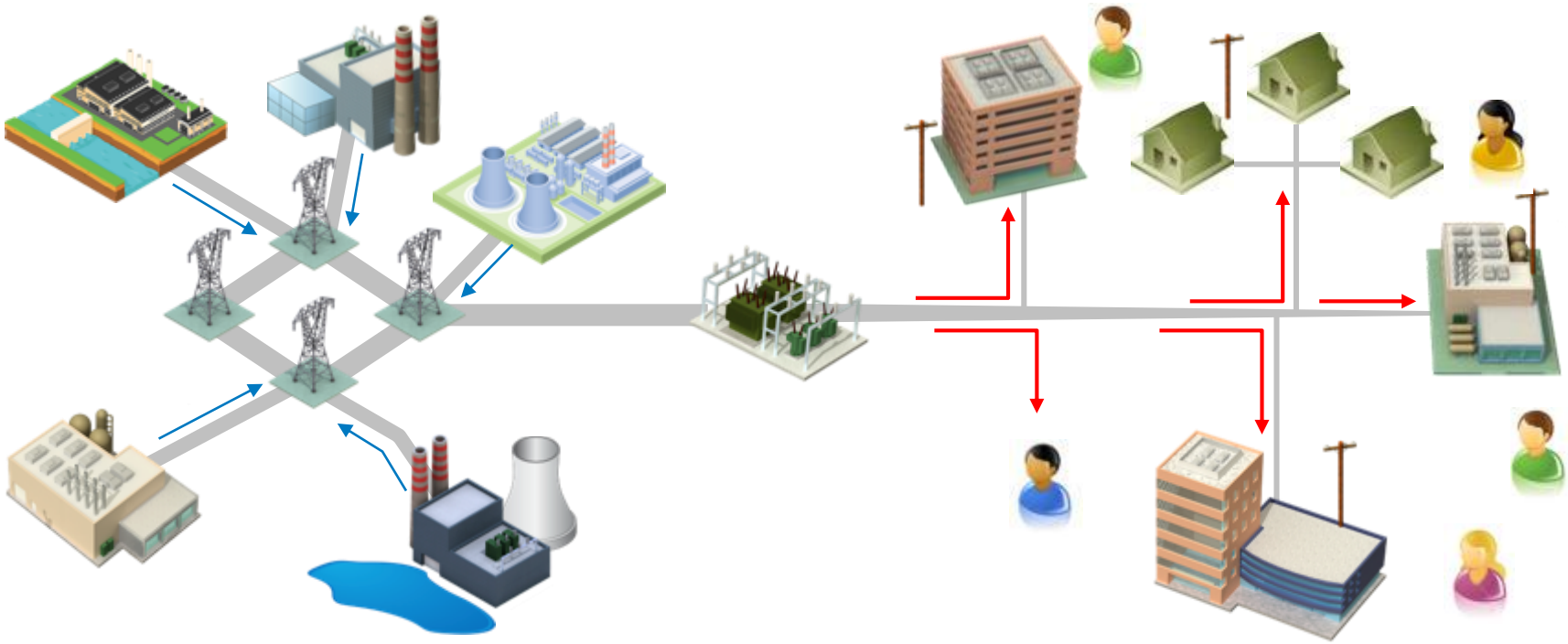
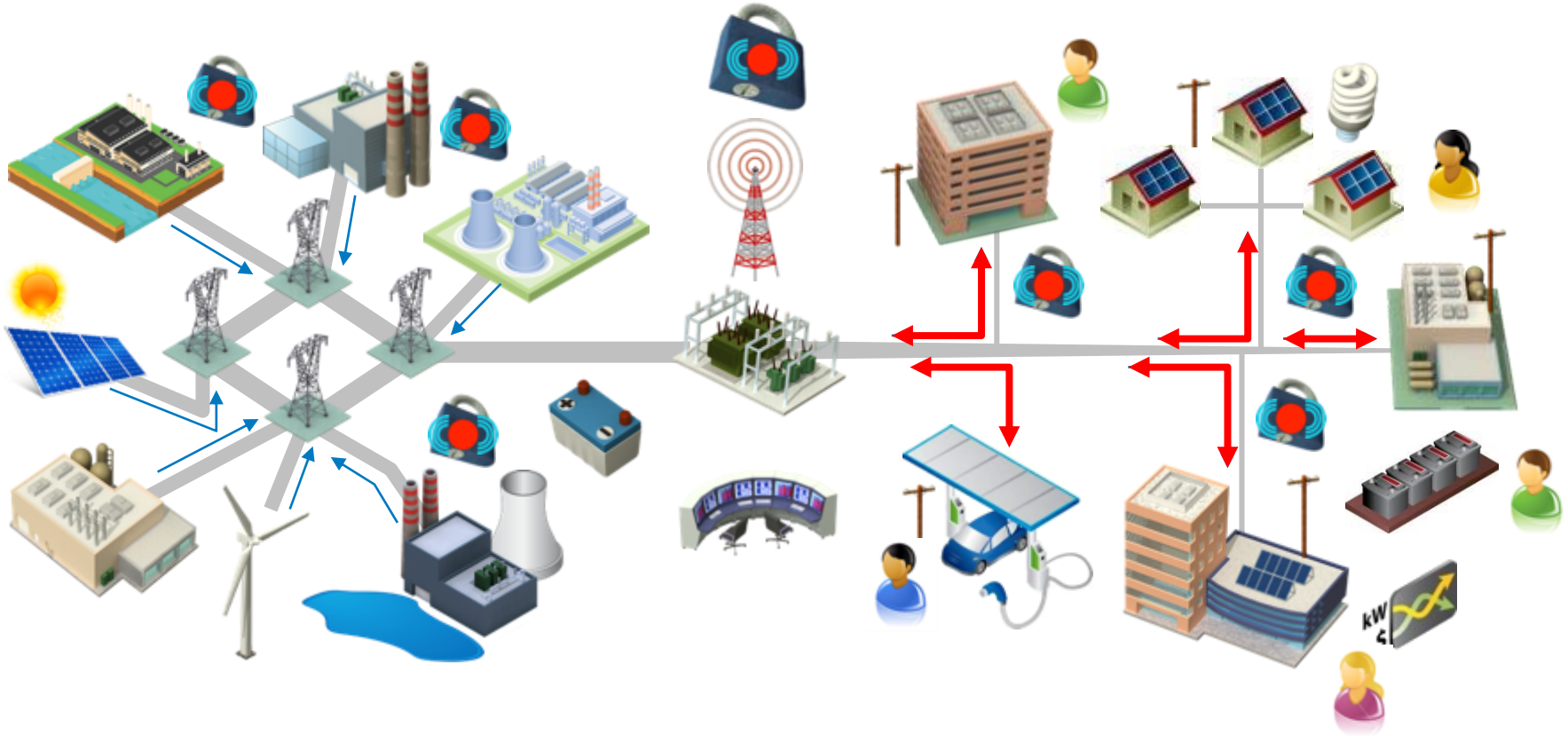
THE GRID OF THE PAST



Generation **Delivery** **Customer**

Source: EPRI, 2009

THE GRID OF THE FUTURE

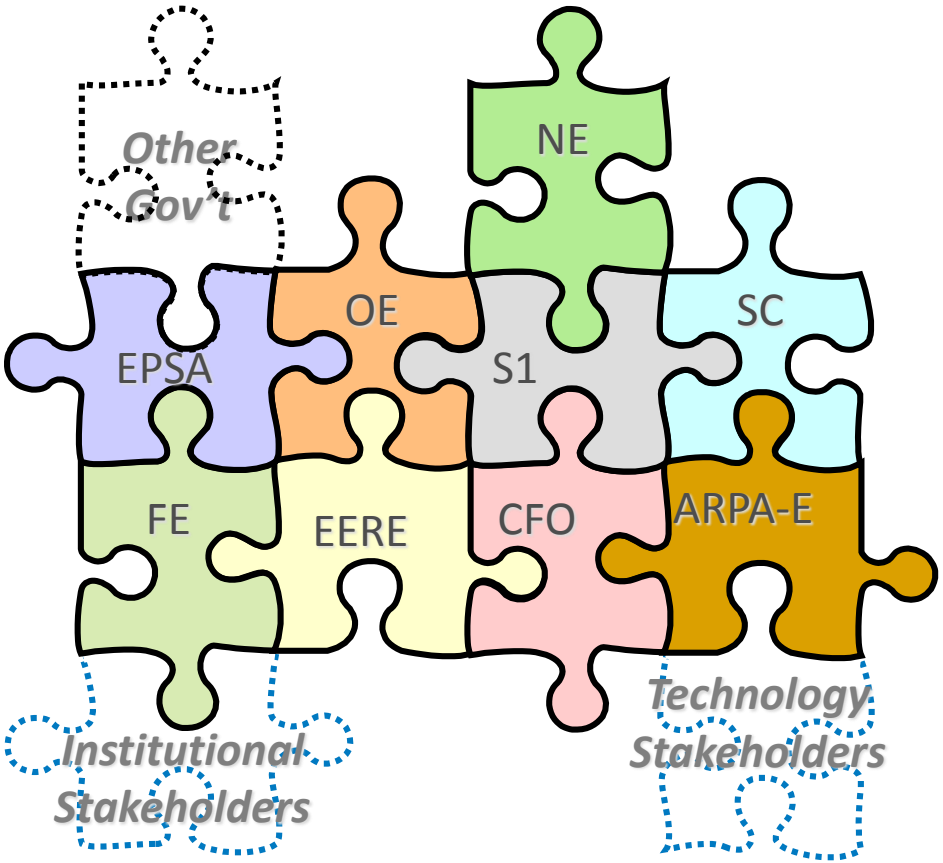


Source: EPRI, 2009

DOE GRID MODERNIZATION INITIATIVE

An aggressive five-year grid modernization strategy for the Department of Energy that includes

- **Alignment of the existing base activities among DOE offices**
- **An integrated Multi-Year Program Plan (MYPP)**
- **New activities to fill major gaps in existing base**
- **Development of a laboratory consortium with core scientific abilities and regional outreach**



GRID MODERNIZATION MULTI-YEAR PROGRAM PLAN

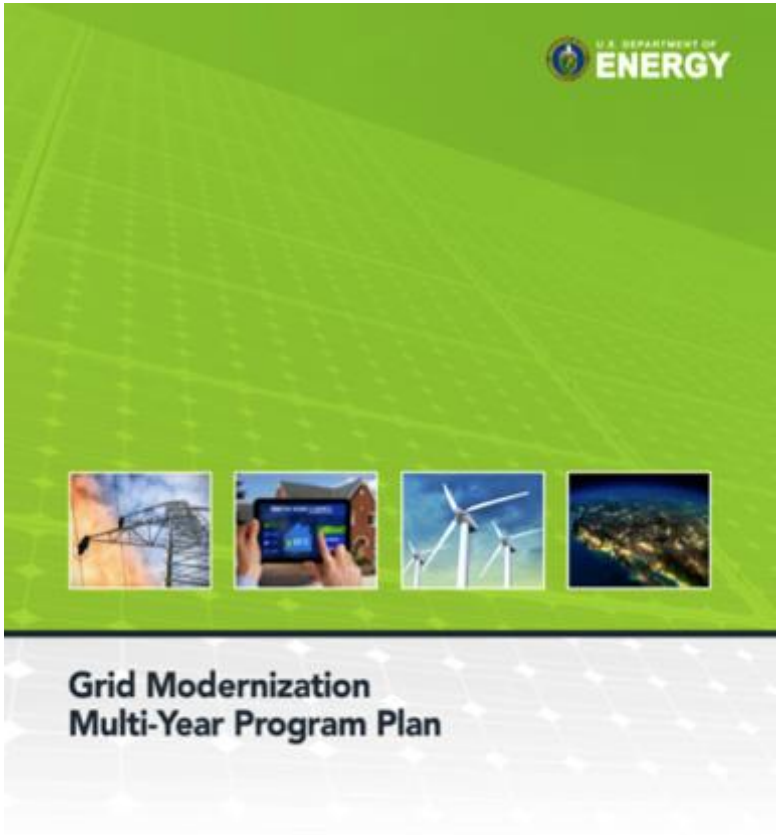
http://energy.gov/downloads/grid-modernization-multi-year-program-plan-mypp

Foundational R&D

- Devices and Integrated Systems
- Sensing and Measurement
- System Operations and Control
- Design and Planning Tools
- Security and Resilience
- Institutional Support

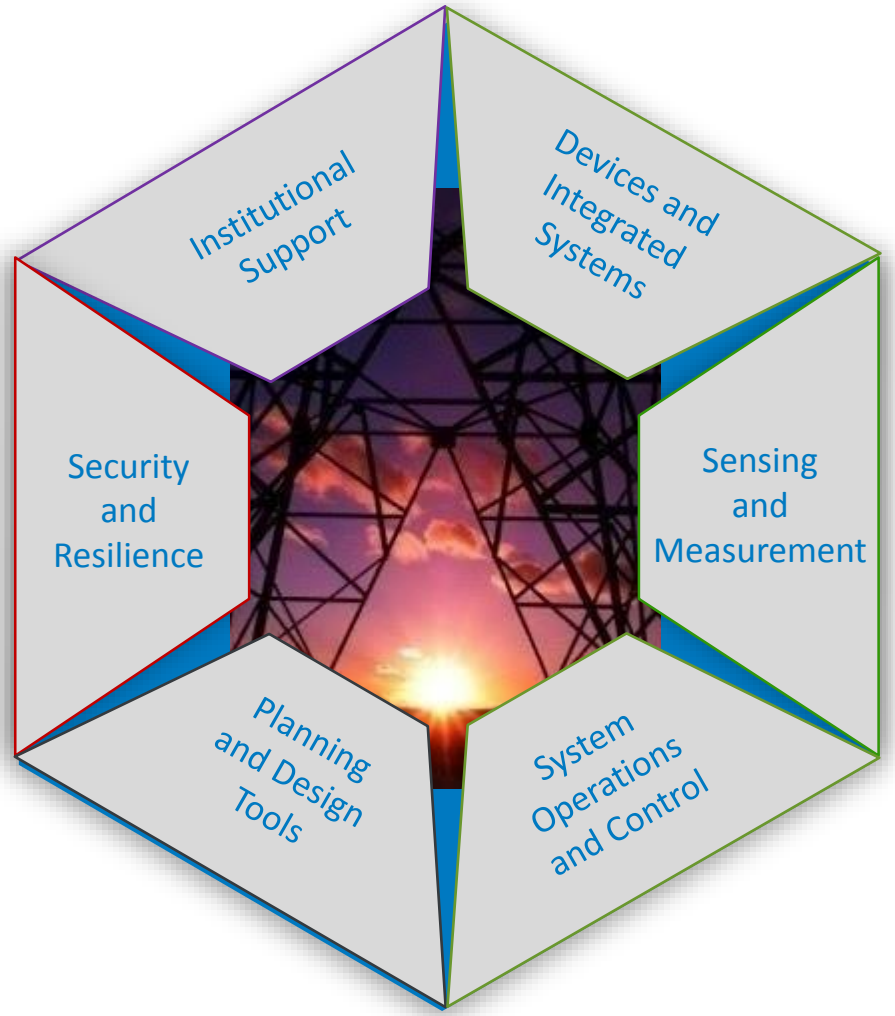
Regional Demonstrations

- Low Reserve Margin Demo
- Clean Distribution Feeder
- Grid Analytics Platform



GRID MODERNIZATION LABORATORY CONSORTIUM

87 projects, $220M over 3 years



http://www.energy.gov/under-secretary-science-and-energy/doe-grid-modernization-laboratory-consortium-gmlc-awards

Energy Systems Integration Facility (ESIF)

Addressing the challenges of large-scale integration of clean energy technologies into the energy systems infrastructure

http://www.nrel.gov/esif

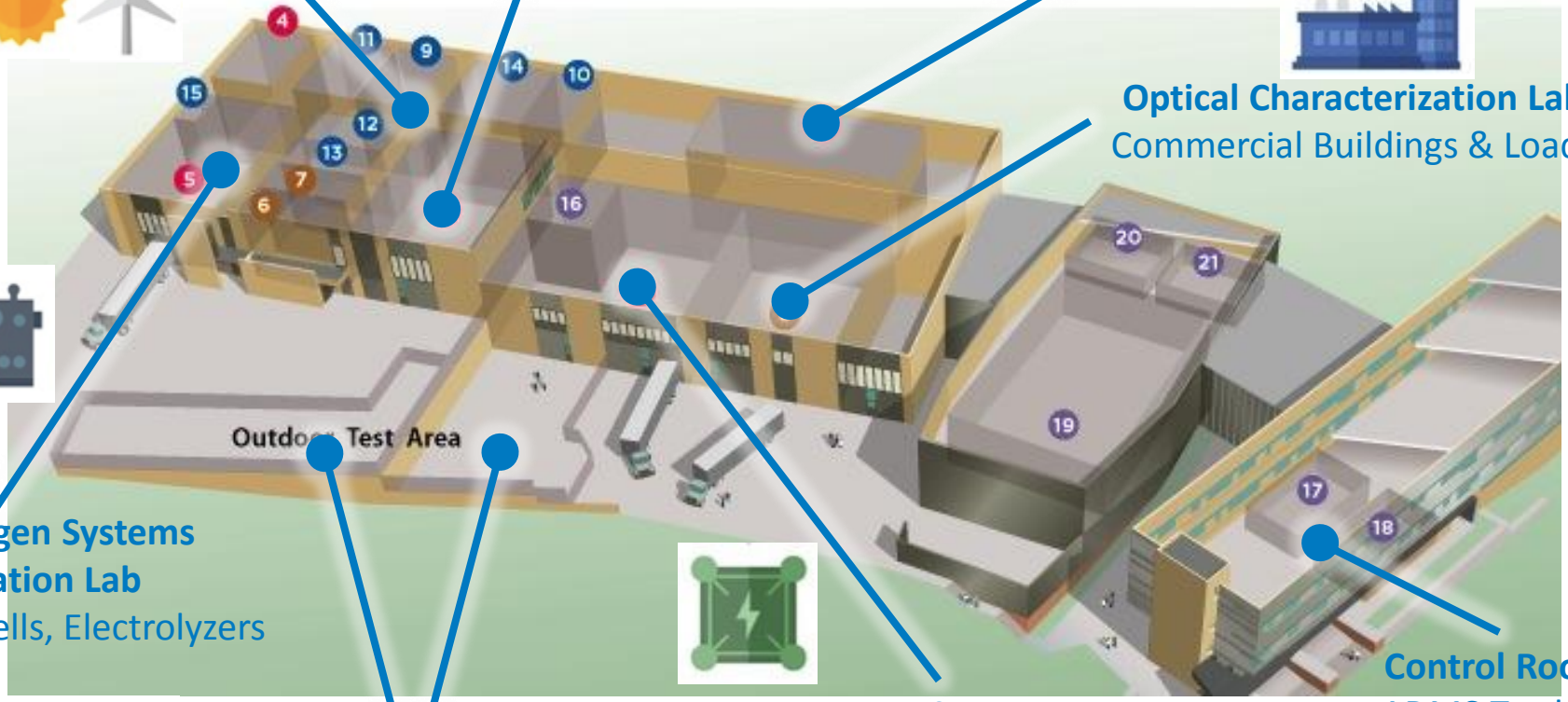
"This new facility will allow for an even stronger partnership with manufacturers, utilities and researchers to help integrate more clean, renewable energy into a smarter, more reliable and more resilient power grid." *- Energy Secretary Ernest Moniz*

NREL NATIONAL RENEWABLE ENERGY LABORATORY | ENERGY SYSTEMS INTEGRATION FACILITY

U.S. DEPARTMENT OF ENERGY

- NREL's largest R&D facility (182,500 ft^2/20,000 m^2)
- NREL's first DOE-designated User Facility
- Space for ~200 NREL staff and research partners
- Petascale HPC and data center supports the entire DOE mission
- Labs focus on R&D of integrated energy systems
  - Electricity
  - Fuels
  - Transportation
  - Buildings
- Integrated electrical, thermal, fuel, water, and data infrastructure

ESIF – A Self-Contained Energy System



Rooftop Test Area
Wind, Solar

Energy Storage Lab
Batteries and Thermal Energy Storage

System Performance Lab
Residential Buildings & Loads

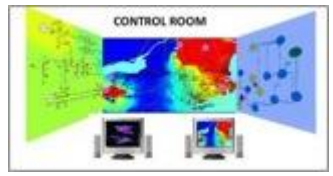
Optical Characterization Lab
Commercial Buildings & Loads

Hydrogen Systems Integration Lab
Fuel Cells, Electrolyzers

Outdoor Test Areas
EVs, Power Transformers, Microturbines, Generators

Power Systems Integration Lab
Power Electronics, Microgrids

Control Room
ADMS Testbed



SolarCity
Hawaiian Electric Company

Research Focus: Load rejection overvoltage control with advanced inverters

Impact:

- Waiting customers connected; 15 MW new rooftop PV enabled.
- Ceiling for distributed PV raised from 120% minimum daytime load to 250%.
- Interconnection standards and codes modified to require advanced inverters.

Next Steps:

- GMLC Hawaii Regional Partnership on Grid Frequency Support

SolarCity

Hawaiian Electric

Puerto Rico Electric Power Authority

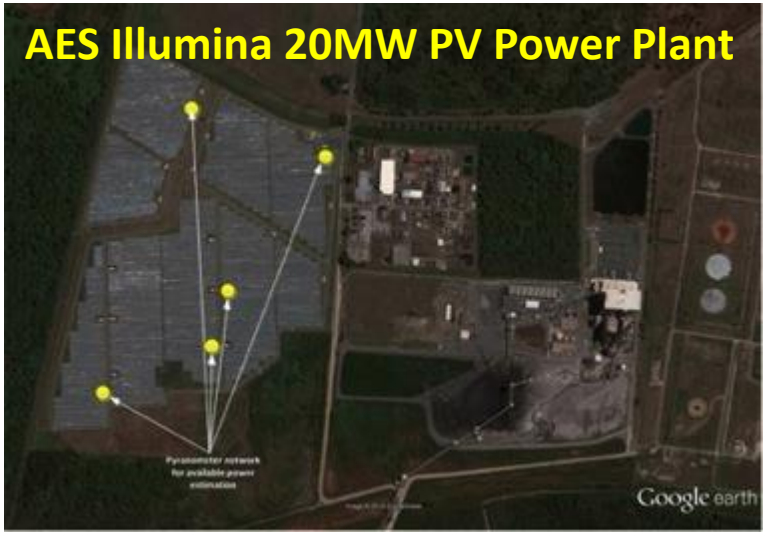
Research Focus: Demonstrate utility-scale solar PV systems can provide needed grid services

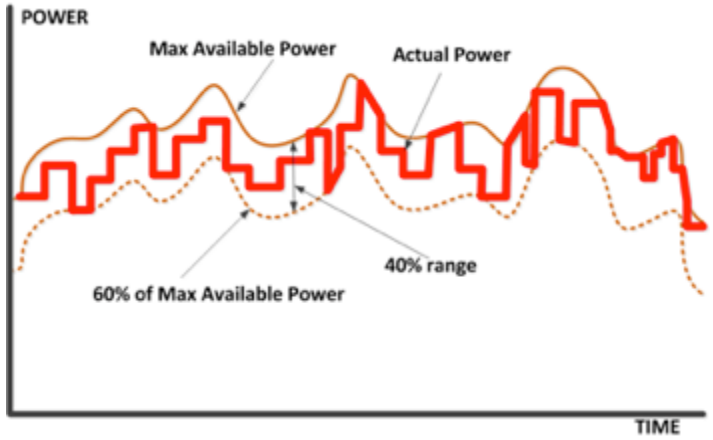
Impact:
First of a kind real world experiment: 20 MW solar plant used for grid stability

- Followed Automatic Generation Control signal
- Provided Up- and Down-Regulation to support frequency
- Deployed all reserve within 500ms
- New controls deployed and validated

Next Steps:

- FirstSolar/CA ISO 300 MW Demo

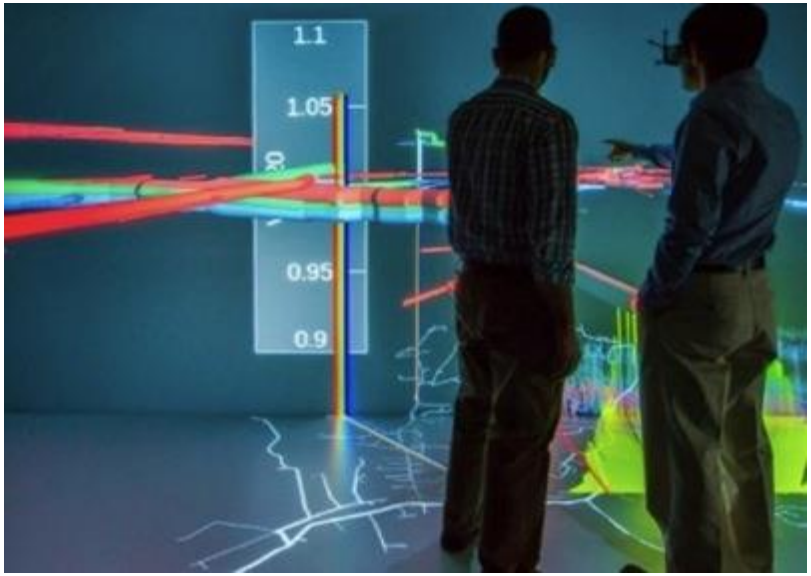




http://www.nrel.gov/docs/fy16osti/65368.pdf

Duke Energy
GE Grid Solutions

Research Focus: Use Distributed Management System (DMS) platform to test voltage control of advanced inverters on a distribution feeder.



Impact:

- Integrated DMS very successful at managing voltage and reducing equipment operations.
- DMS linked with power hardware-in-the-loop grid simulation.

Next Steps:

- GMLC Open Advanced DMS Project with Testbed

ESIF SUCCESS STORIES

Smarter Grid Solutions

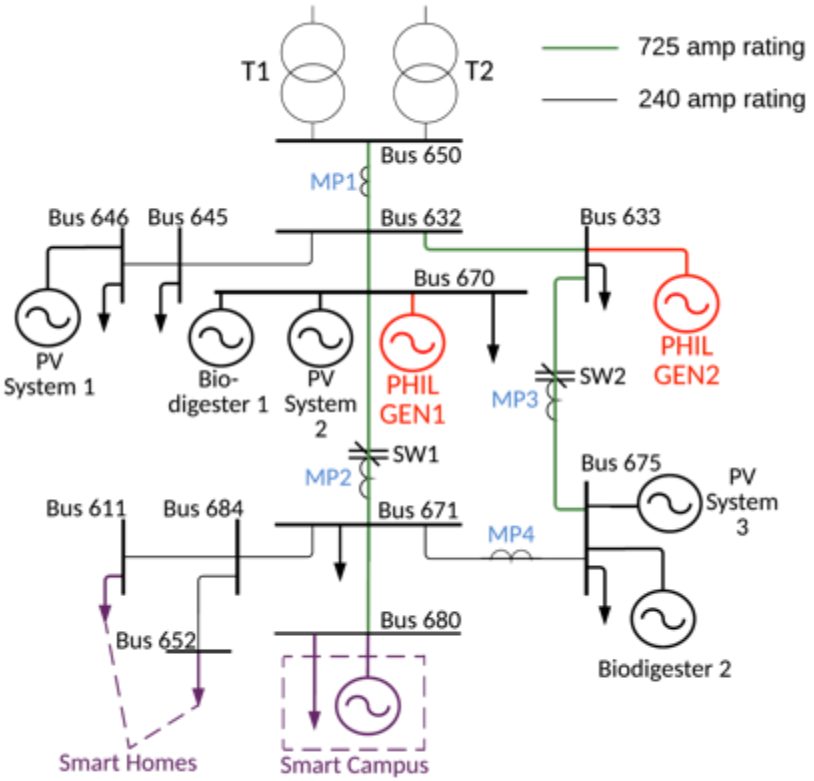
Research Focus: Show that "active network management" can increase DER on distribution grids to >50% penetration.

Impact:

- Demonstrated "smart home" use case: integrated and coordinated control of residential PV, EV charging, and battery storage.
- Demonstrated "smart campus" use case ability to manage larger PV, controllable loads, EV charging, and battery storage.

Next Steps:

- Deployment in CA and NY



http://www.nrel.gov/esi/news/2016/27963

FOR MORE INFORMATION

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

http://www.energy.gov/under-secretary-science-and-energy/grid-modernization-initiative