Government-University-Industry Roundtable

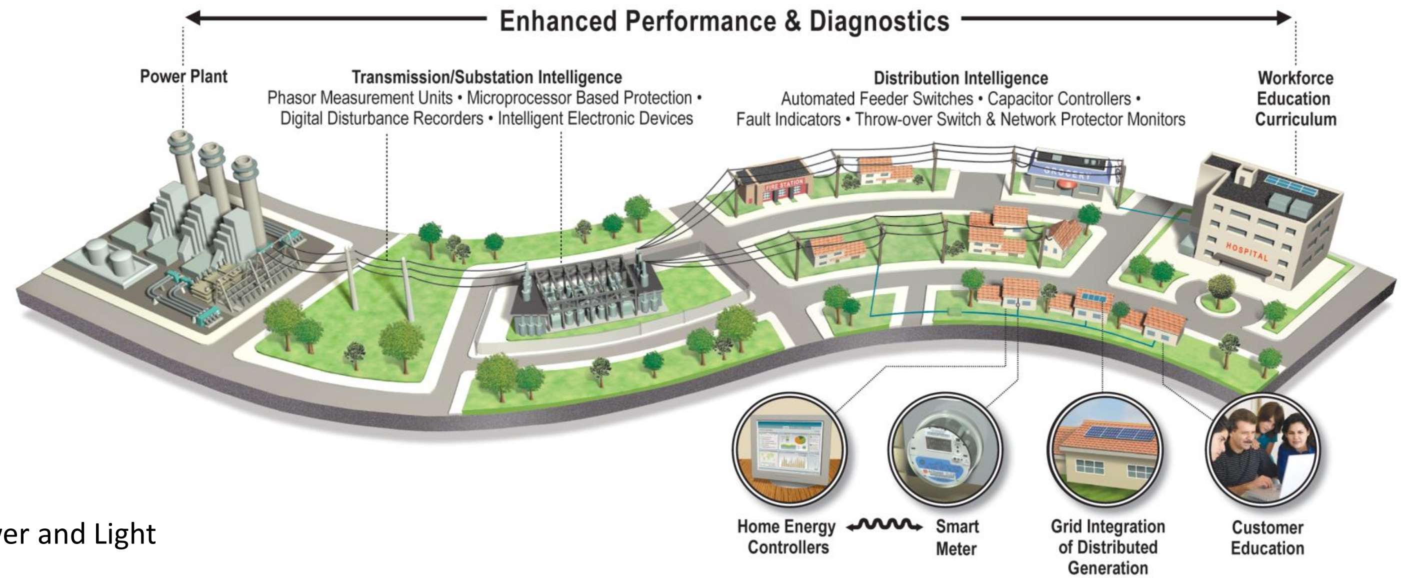
National Academy of Sciences
February 10, 2015

Smart Grids need Smart People

Department of Energy, Office of Electricity Delivery and Energy Reliability
Deputy Assistant Secretary Hank Kenchington

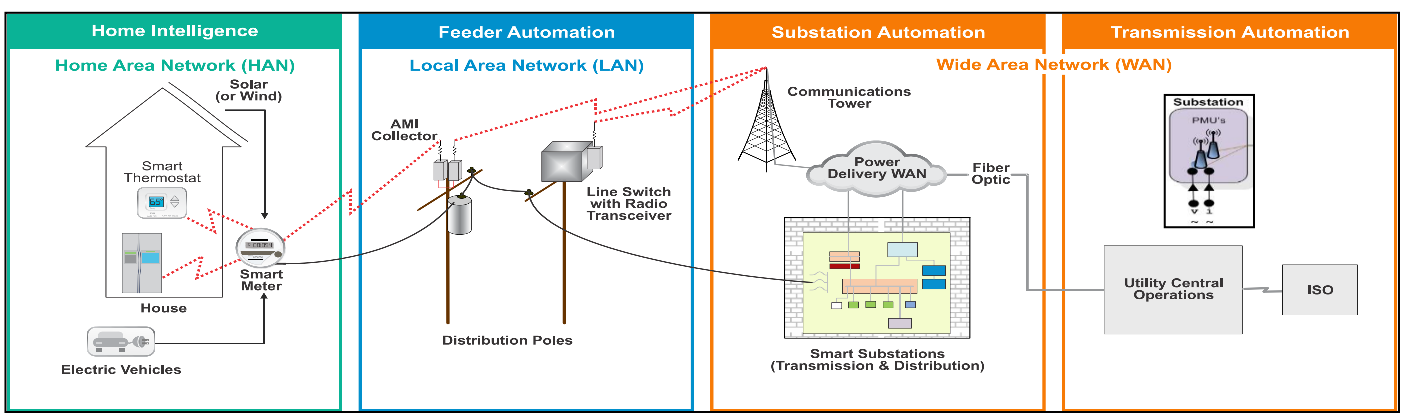
Smart Grid enables grid modernization with advanced communications and controls

...provides seamless, secure communications across multiple interconnected domains and platforms



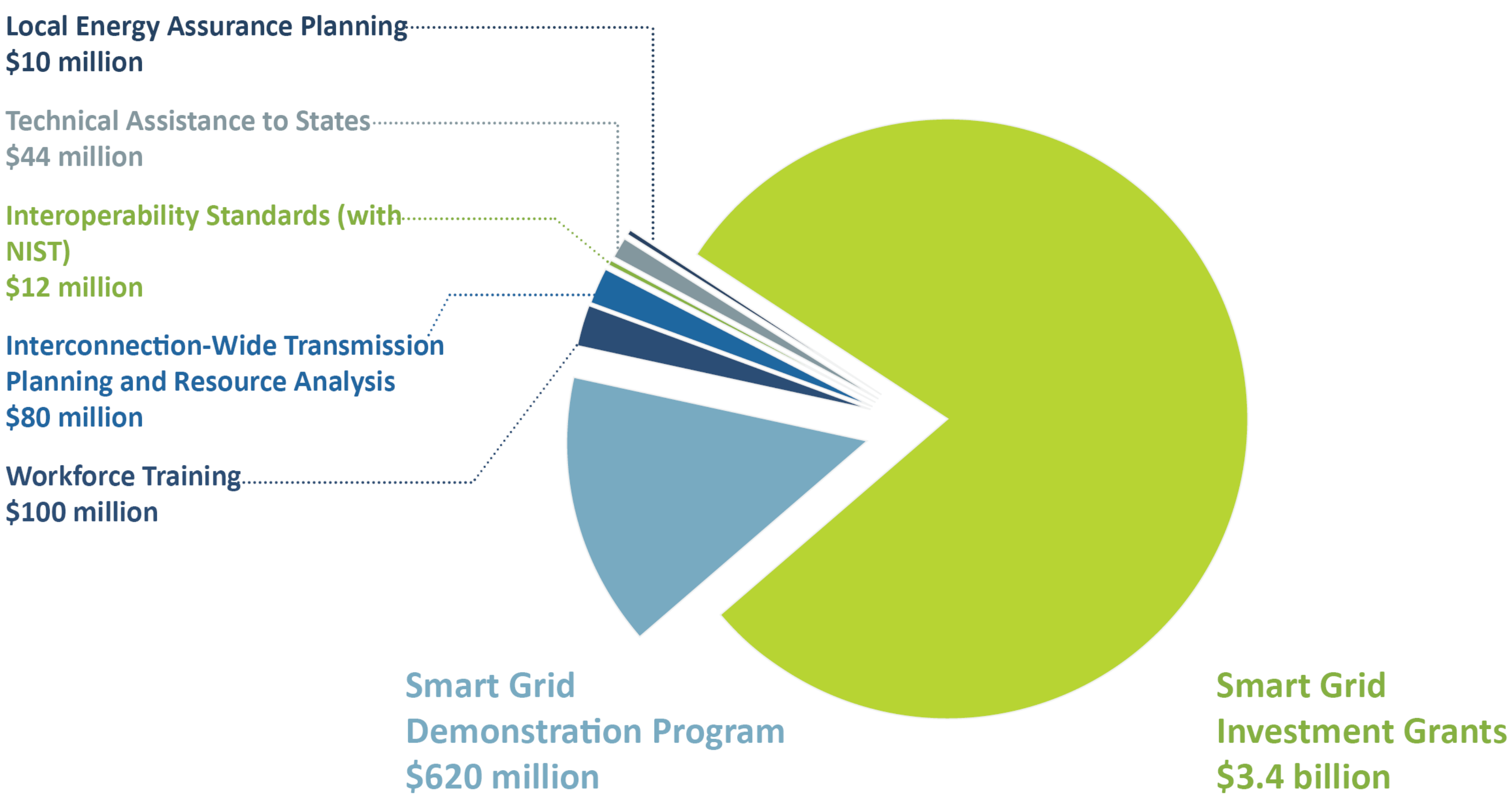
Source: Florida Power and Light

Generic Smart Grid Communications Architectures



Recovery Act Grid Modernization Programs

One-Time Appropriation: $4.5 Billion Recovery Act Funds



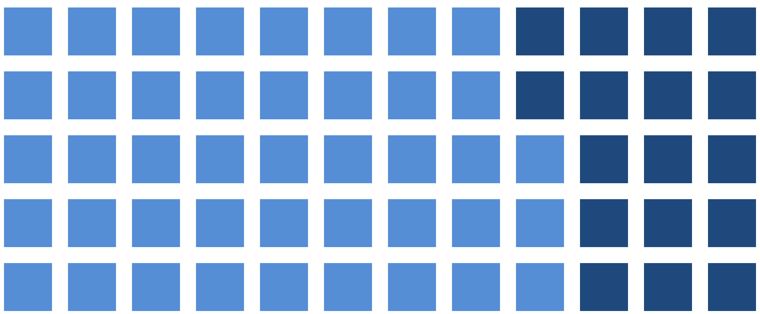
Originally authorized by the Energy Infrastructure Security Act 2007, EISA 1306 and EISA 1304

Grid Modernization Investments

SGIG projects *accelerate* industry investment to achieve a modern grid

ARRA Spending **$7.9 billion with cost share to be spent through 2015**

EPRI Estimate



$338 - $476 billion needed through 2030

EPRI. Estimating the costs and benefits of the smart grid: A preliminary estimate of the investment requirements and the resultant benefits of a fully functioning smart grid. EPRI, Palo Alto, CA; 2011.

Brattle Group Estimate

$880 billion needed through 2030

Chupka, M.W. Earle, R., Fox-Penner, P., Hledik, R. Transforming America's power industry: The investment challenge 2010 – 2030. Edison Electric Institute, Washington D.C.,: 2008.

Key Technologies and Systems for Smarter Grids

Electric Transmission Systems	Electric Distribution Systems	Advanced Metering Infrastructure	Customer Systems
			
• Synchrophaser technologies • Communications infrastructure • Wide area monitoring and visualization • Line monitors	• Automated switches • Equipment monitoring • Automated capacitors • Communications infrastructure • Distribution management systems	• Smart meters • Communications infrastructure • Data management systems • Back-office integration	• In-home displays • Programmable communicating thermostats • Home area networks • Web portals • Direct load controls • Smart appliances

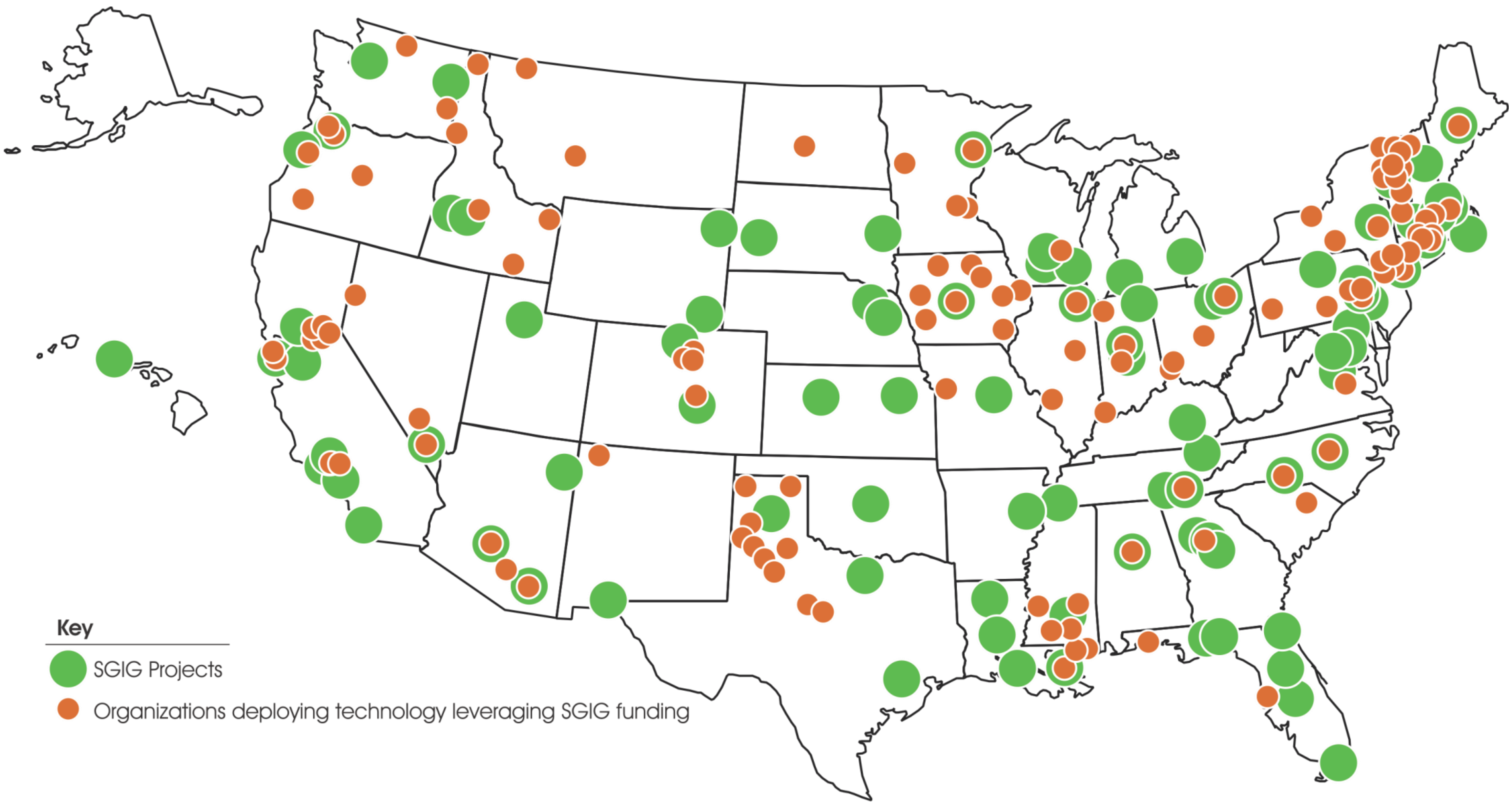
Smart Grid Technologies Provide a Wide Range of Benefits

Benefits	Smart Grid Technology Applications					
	Consumer-Based Demand Management Programs (AMI-Enabled)	Advanced Metering Infrastructure (AMI) Applied to Operations	Fault Location, Isolation and Service Restoration	Equipment Health Monitoring	Improved Volt/VAR Management	Synchrophasor Technology Applications
	• Time-based pricing • Customer devices (information and control systems) • Direct load control (does not require AMI) * *Shifting peak demand may or may not lower emissions	• Meter services • Outage management • Volt-VAR management • Tamper detection • Back-Office systems support (e.g., billing and customer service)	• Automated feeder switching • Fault location • AMI and outage management	• Condition-based maintenance • Stress reduction on equipment	• Peak demand reduction • Conservation Voltage Reduction • Reactive power compensation	• Real-time and off-line applications
Capital expenditure reduction – enhanced utilization of G,T & D assets	✔			✔	✔	✔
Energy use reduction	✔	✔	✔		✔	✔
Reliability improvements		✔	✔	✔		✔
O&M cost savings		✔	✔	✔		
Reduced electricity costs to consumers	✔*				✔	
Lower pollutant emissions	✔	✔	✔		✔	✔
Enhanced system flexibility – to meet resiliency needs and accommodate all generation and demand resources	✔	✔	✔	✔	✔	✔

SGIG – 99 Projects Funded at $7.9 Billion
(includes public and private investments)

	Total Funds	Planned Installations	Expected Benefit
	*Transmission* $537 million	**> 800** phasor measurement units	Real-time voltage and frequency fluctuations visible across the system
	*Distribution* $2.06 billion	**>7,500** automated switches **~18,500** automated capacitors	Outage management, improved reliability, and VAR control
	*AMI* $4.50 billion	**>15.5 million** smart meters	Operational savings: fewer truck rolls, automated readings, reduced outage time
	*Customer Systems* $0.80 billion	**~365,000** direct control devices **~240,000** PCTs **~8,000** in-home displays	Increased customer control; reduced peak demand

SGIG projects span the nation



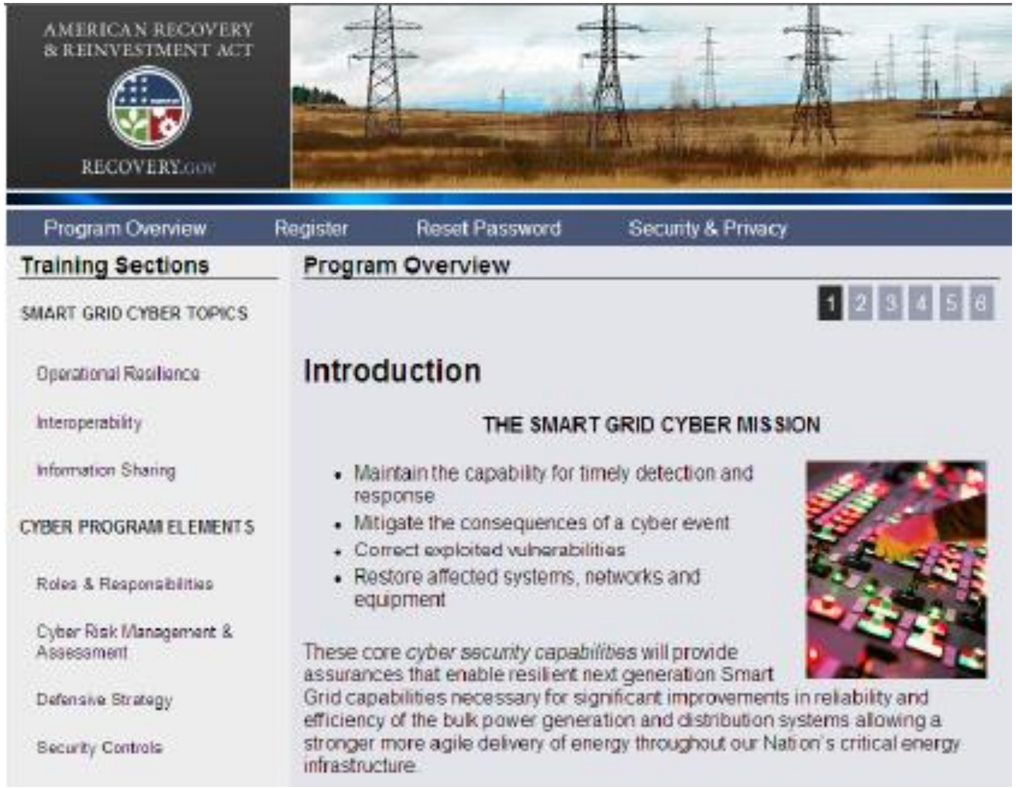
99 Projects involving 228 Utilities and other Organizations

Cybersecurity Built-in to ARRA Smart Grid

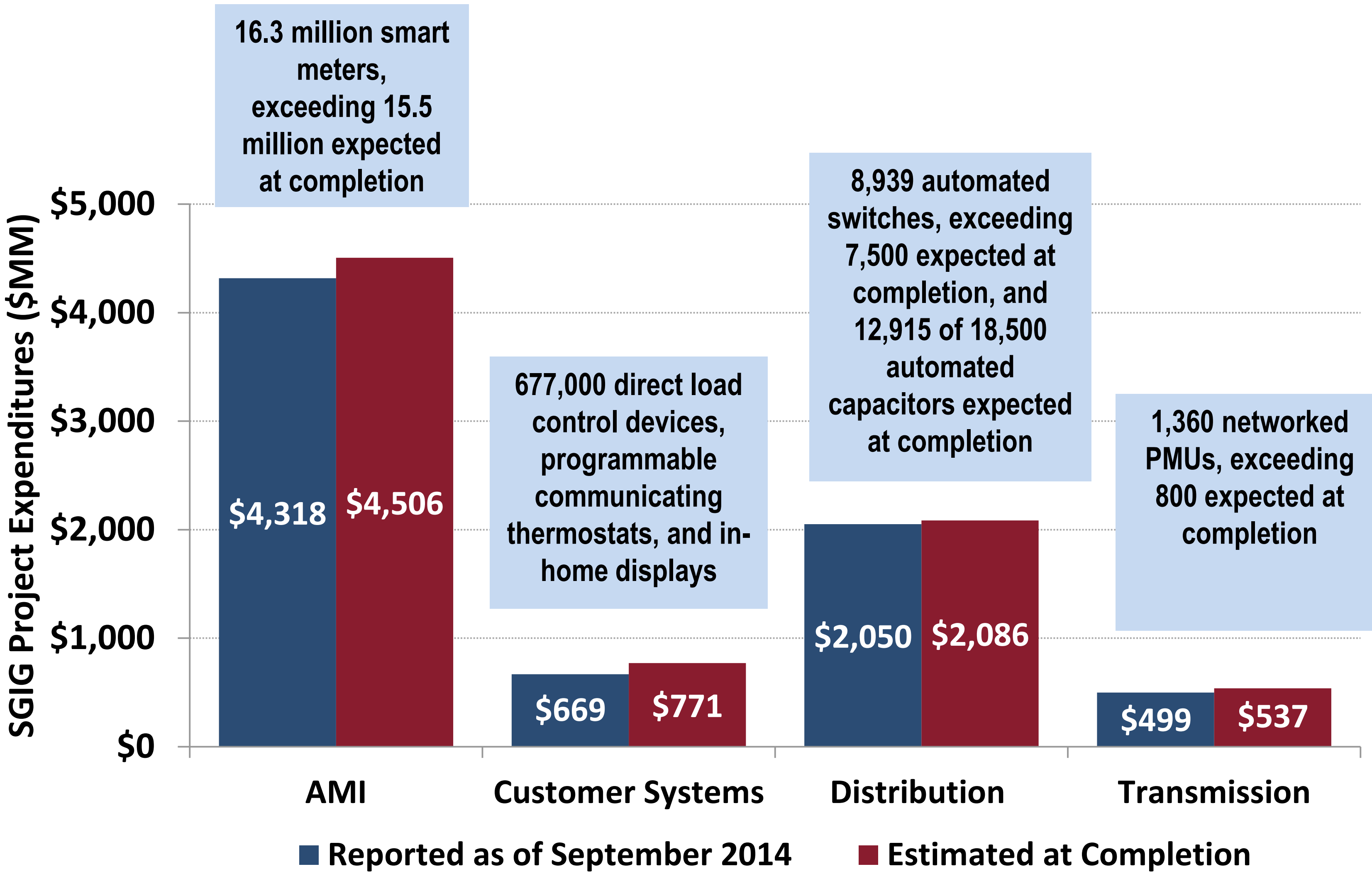
- **Cyber security requirements developed by interagency team**
  (DOE, NIST, FERC, DHS, CIA)
- **Each project required to develop Cybersecurity Plans (CSP)** – approved/monitored by DOE & signed by Recipient Corporate Officer
  - Held two Cybersecurity Information Exchange Workshops
  - Progress monitored during annual site visits
- **Risk assessment and mitigations required** across engineering life cycle of project

ARRA Cyber Security Website

www.ARRAsmartgridcyber.net



SGIG Deployment Status - Sept 30, 2014



Early Results Show Tangible Benefits

Customer Systems

Oklahoma Gas and Electric

Time-of-use and variable peak / critical peak pricing with in-home customer device use enabled up to 30% peak demand reduction (which could offset a new peaking plant) and lowered customer bills by up to $150

Distribution

Electric Power Board of Chattanooga

Advanced automated circuit smart switches and sensor equipment will enable 40% reduction in customer outage minutes – worth $35 million/year to customers

AMI

Talquin Electric Cooperative

In 2011 and 2012, smart meters avoided 6,000 truck rolls for service connections and disconnections and 9,000 for non-payments saving more than $640,000. In 2013, they avoided an additional 18,640 truck rolls for meter operations and saved an additional $1,016,510.

Transmission

Western Electricity Coordinating Council

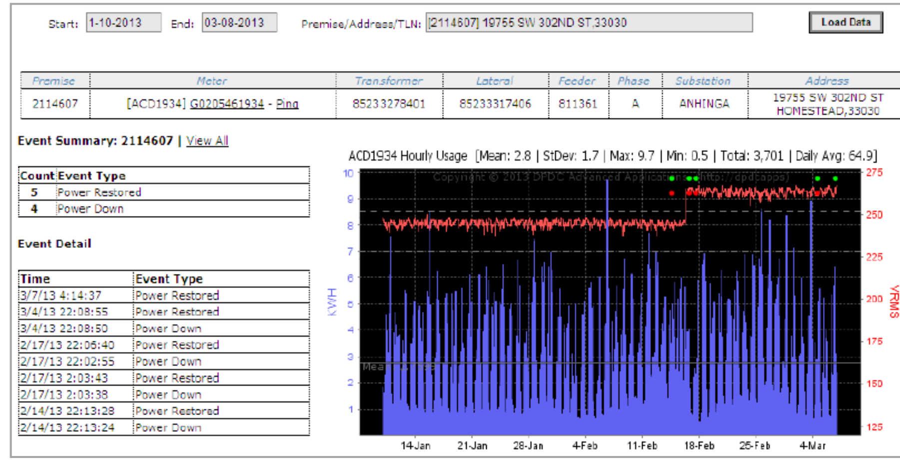
18 transmission owners installing and connecting 393 PMUs and 57 PDCs and synchrophasor data was used in forensic analysis of the September 2011 Southwest outage

Equipment Health Monitoring With AMI - FPL Transformer Project

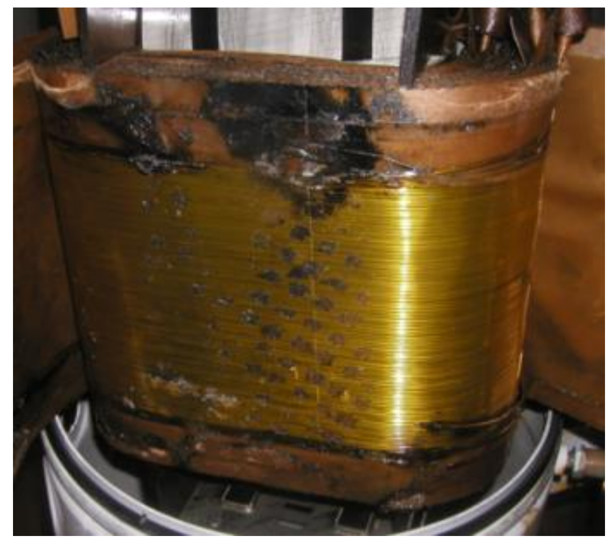
- FPL used smart meter data to identify transformer voltage shifts, indicating deteriorations in transformer performance and potential equipment failure.
- This approach allows for pro-active transformers replacement (shifting from schedule-based maintenance to condition-based maintenance).
- Through Q3 2014, FPL had replaced more than 1,000 distribution transformers, preventing potential unplanned outages for an estimated 10,000 customers.

Benefits of Proactive
High-voltage Transformer Replacement

- Average outage time is 93 minutes shorter than an unplanned transformer replacement
- Costs are 25% lower than unplanned replacements
- Can improve customer perceptions
- Reduces potential for customer claims



Voltage shift indicating possible equipment degradation



Damage to primary winding of high-voltage transformer identified through smart meters

Sources: http://www.ieee-pes.org/presentations/gm2014/FPL-IEEE-Presentation-Big-Data-July-2014.pdf
https://www.smartgrid.gov/sites/default/files/doc/files/B2-Master-File-with-edits_120114.pdf

Consumer Behavior Studies

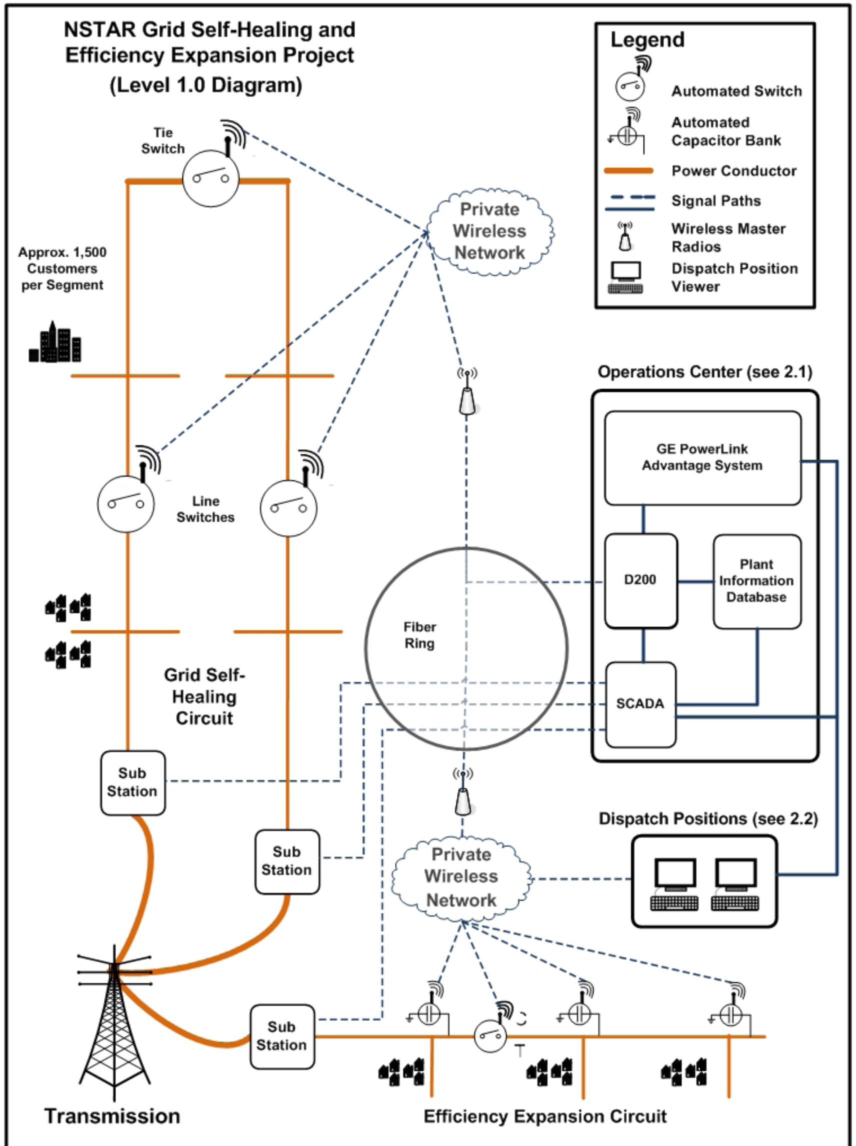
	CEIC	DECO	GMP	Lake land	MMLD	MN Power	Nevada Power	Sierra Pacific Power	OG&E	SMUD	VEC	**Total**
Rate Treatments												
CPP		●	●		●	●	●	●	●	●		**8**
TOU		●		●		●	●	●	●	●		**7**
VPP									●		●	**2**
CPR	●		●									**2**
Non-Rate Treatments												
IHD	●	●	●						●	●		**5**
PCT	●	●					●	●	●			**5**
Education							●	●				**2**
Web						●						**1**
Recruitment Method												
Opt In	●	●	●	●	●	●	●	●	●	●	●	**11**
Opt Out						●			●		●	**3**

Peak Demand Reduction from AMI, Pricing, and Customer Systems

Selected examples from SGIG projects reporting initial results

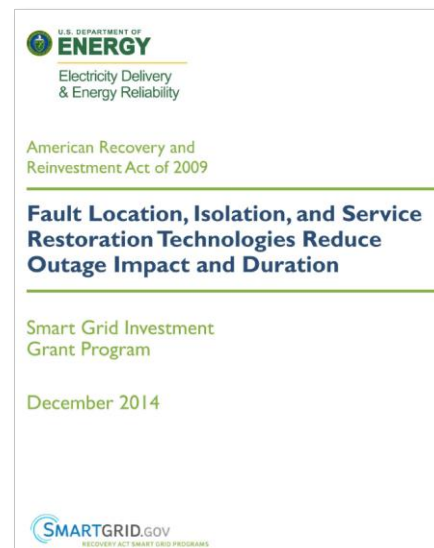
Project Elements	OG&E 770,000 customers	MMLD 11,000 customers	SVE 18,000 customers
Customers Tested	6,000 residential	500 residential	600 mostly residential
Time-Based Rate (s)	TOU and VPP, w/CPP	CPP	CPP
Customer Systems	IHDs, PCTs, and Web Portals	Web Portals	Web Portals
Peak Demand Reduction	Up to 30% 1.3 kW/customer (1.8kW/customer w/CPP)	37% 0.74 kW/customer	Up to 25% 0.85 kW/customer
Outcome	**Deferral of 170 MW of peak capacity by 2016 with 20% participation**	**Lowers total purchase of peak electricity**	**Lowers total purchase of peak electricity**
Customer Acceptance	Positive experience, many reduced electricity bills	Positive Experience, but did not use the web portals often	Interested in continued participation, many reduced electricity bills

FLISR - Fault Location Isolation and System Restoration Technologies Show Fewer and Shorter Outages



- **Reduced the number of customers interrupted** for partial-feeder outages (by about 55%) and full-feeder interruptions (by about 37%).
- **Reduced the number of customer minutes of interruption** for partial-feeder outages (by about 50%) and full-feeder outages (by about 51%).

Data from **CenterPoint Energy**, **Duke Energy**, **NSTAR Electric Company**, **Pepco Holdings, Inc.**, **Southern Company**, **Alabama Power**, **Georgia Power**, **Gulf Power**, and **Mississippi Power**


U.S. DEPARTMENT OF ENERGY

Electricity Delivery & Energy Reliability

American Recovery and Reinvestment Act of 2009

Fault Location, Isolation, and Service Restoration Technologies Reduce Outage Impact and Duration

Smart Grid Investment Grant Program

December 2014

SMARTGRID.GOV

Intelligent Switches and Advanced Communications Improve Reliability

Selected examples from SGIG projects reporting initial results

4 Projects involving 1,250 feeders

April 1, 2011 through March 31, 2012

Index*	Description	Weighted Average (Range)
SAIFI	**System Average Interruption Frequency Index (outages)**	**-22 %** (-11% to -49%)
MAIFI	**Momentary Average Interruption Frequency Index (interruptions)**	**-22 %** (-13% to -35%)
SAIDI	**System Average Interruption Duration Index (minutes)**	**-18 %** (+4% to -56%)
CAIDI	**Customer Average Interruption Duration Index (minutes)**	**+8 %** (+29% to -15%)

*Voluntary indices to measure reliability

Weighted average based on numbers of feeders

Smart Grid Technologies Enhance Resilience

Electric Power Board (EPB) of Chattanooga

- **power outages were costing community $100 million/yr**
- **Installed automated fault isolation and service restoration technology (FLISR) (more than 1200 automated feeder switches)**

2011 Labor Day Storm (20% technology configured):

- 63,000 homes interrupted; however, **16,000 (25%) experienced no outage** and **9,000 (7%) experienced a 2-second interruption**
- Utility avoided 1,917,000 customer minutes of interruption

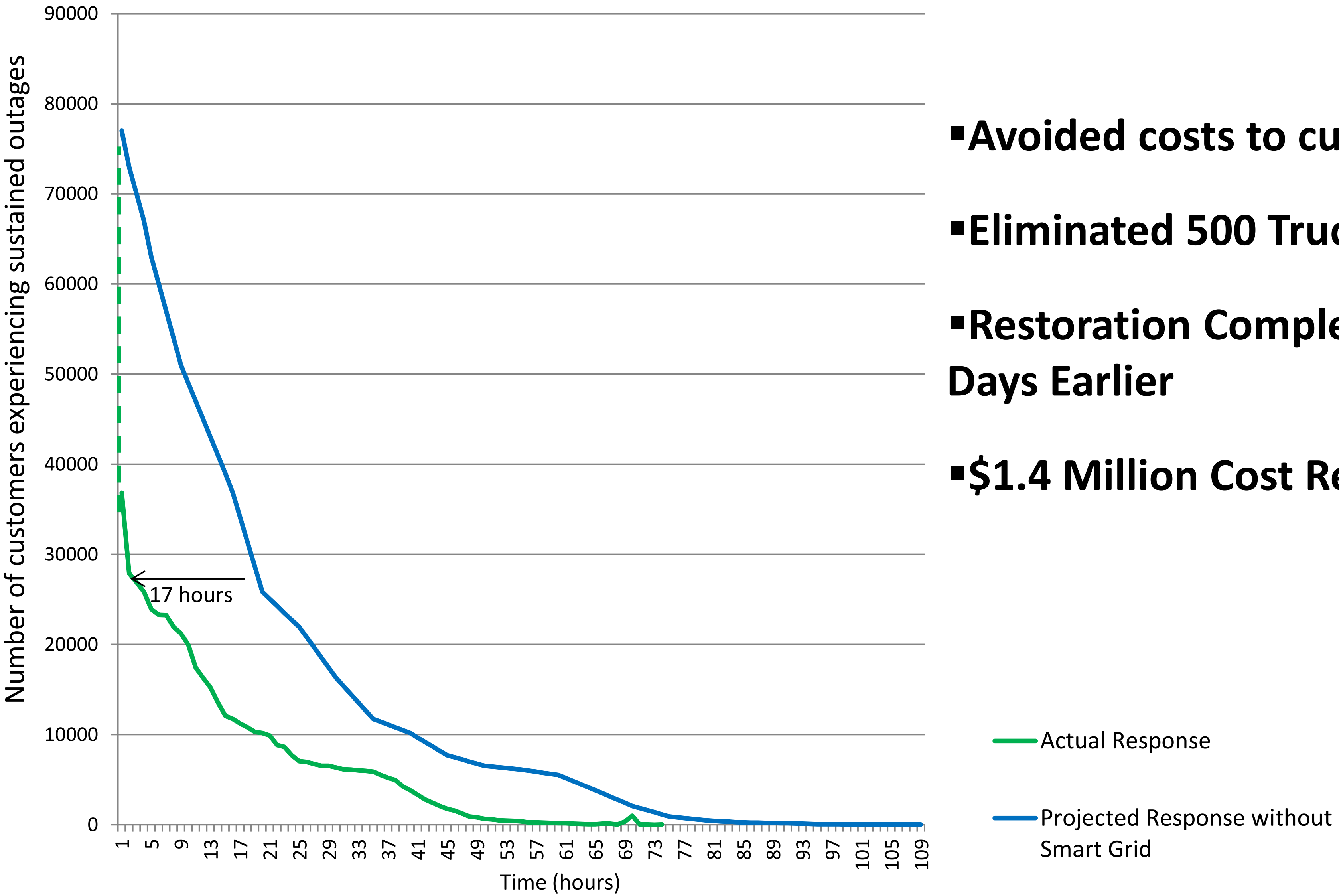
July 2012 wind storm:

- EPB estimates that due to automated feeder switching with AMI they were able to **avoid 500 truck rolls** and **reduce total restoration time by 1.5 days**
- Represents **$1.4 million in operational savings**

February 2014 snow storm:

- **Avoided sustained outage for 37,000 customers**
- Restored power about **36 hours earlier**, 16 hours due to self healing smart switches and 20 hours due to smart meter's ability to verify outage status and redirect crews efficiently.
- **Saved $1.4 million** in overtime costs for field crews.

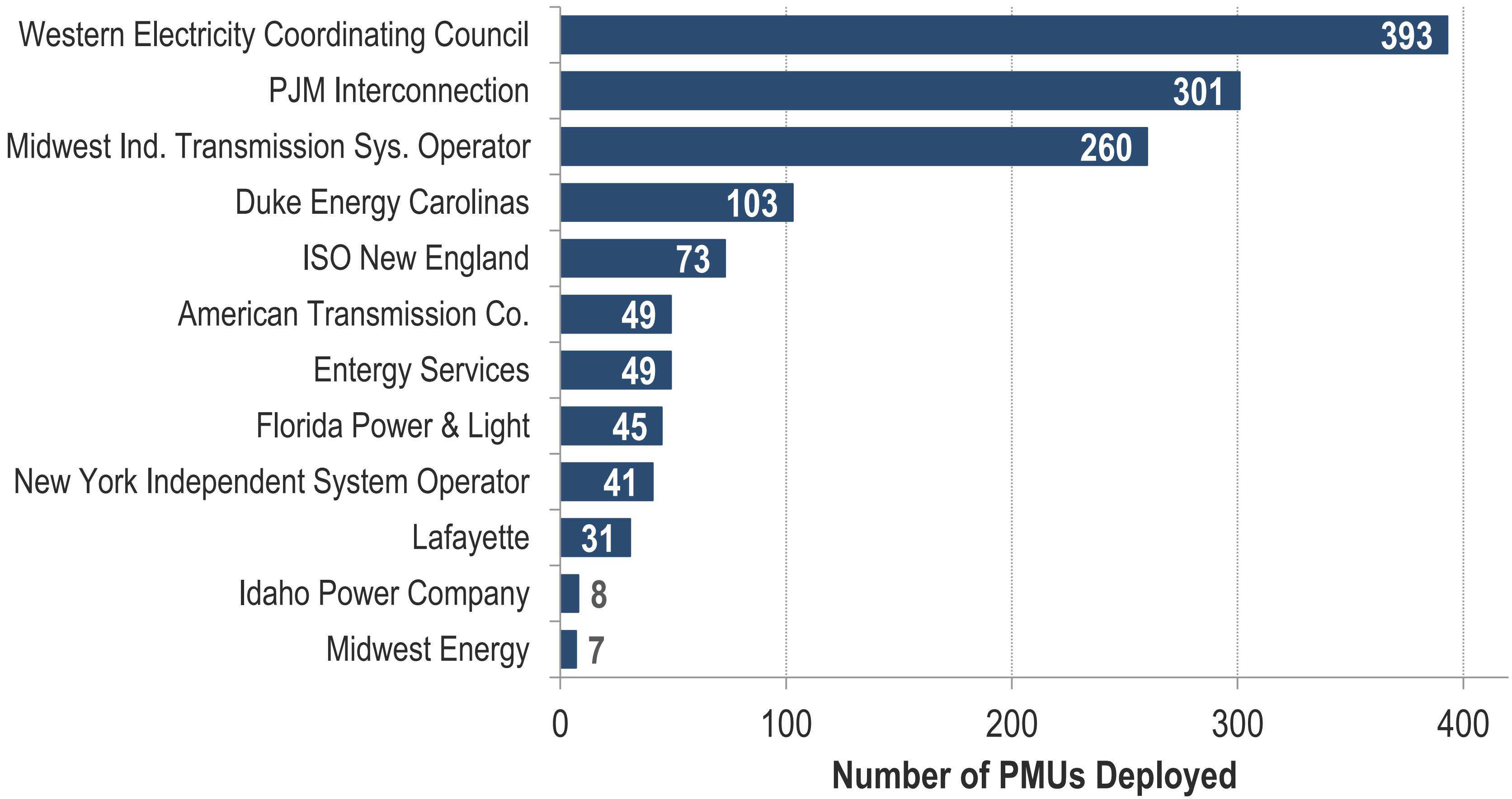
EPB July 5, 2012 Storm Response



- Avoided costs to customers
- Eliminated 500 Truck Rolls
- Restoration Complete 1 ½ Days Earlier
- $1.4 Million Cost Reduction

Electric Transmission System PMU Deployment Progress by Project

Progress of SGIG PMU Deployments by the Synchrophasor Projects (based on recipient reporting data as of September 2014) – 1360 PMUs

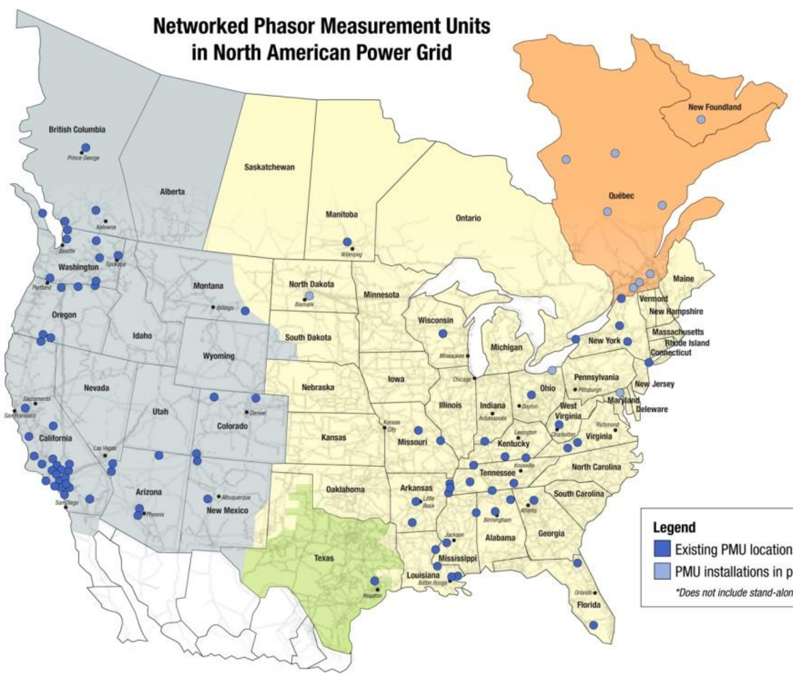


ARRA Smart Grid investments create nationwide sensor network to better detect grid disturbances

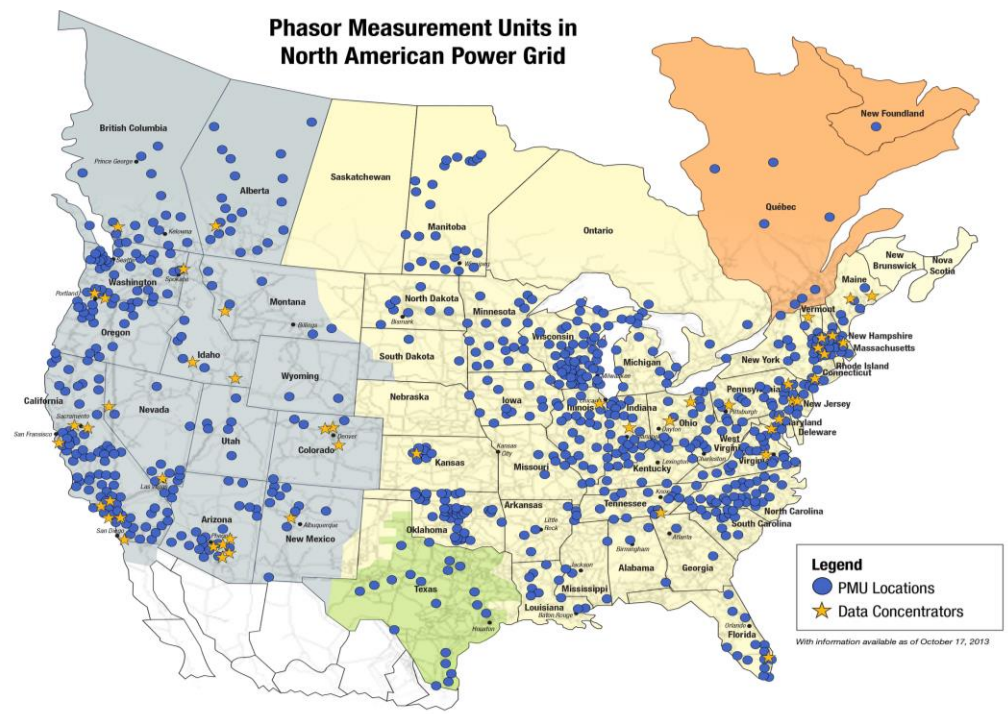
As of October 2013, almost 1,700 PMUs are in service.

Most are networked, and most were funded by Smart Grid Investment Grant funds and matching private sector funds.

April 2007



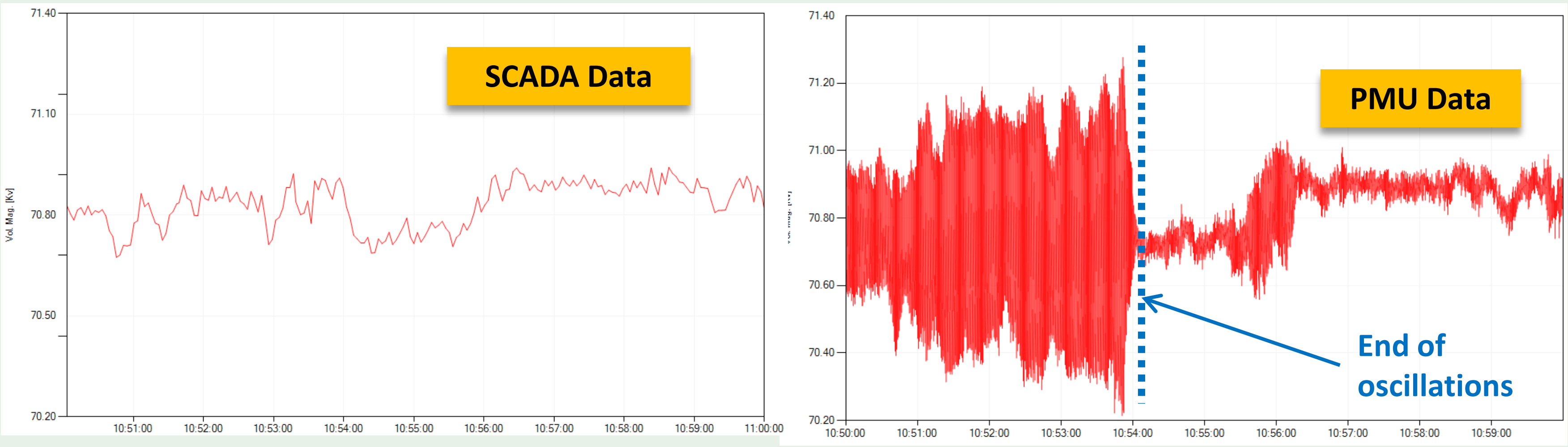
October 2013



Oscillation Detection with PMUs

Examples:

- WECC – Oscillation at wind plant discovered
- ISO-NE – Identified oscillation mode at 0.12 Hz, which reached 100MW peak-to-peak
- Idaho Power Company – Identified oscillation modes at 0.2, 0.6, 1.4 and 1.6 Hz
- Duke Energy Carolinas detected oscillation of hydropower unit



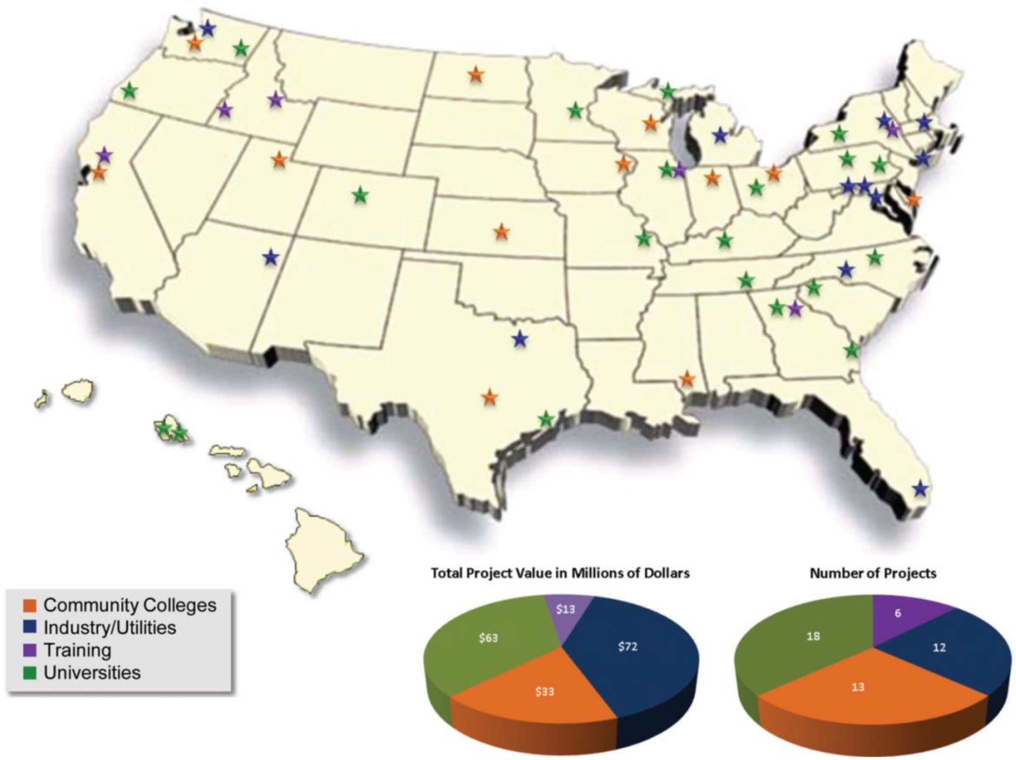
Comparison between voltage signal from the event as captured by SCADA vs. PMU data for WECC wind farm oscillations

Oscillatory behavior (invisible to SCADA) is indicative of improperly set controls, inadequately modeled generation or load, or malfunctioning equipment (or other issues) that can lead to catastrophic system failure

ARRA awards $100 Million for Smart Grid Workforce Training and Development

> *"The percentage of the lineworker workforce expected to retire within the next five to ten years could approach 50% in some organizations "*
>
> "Report to Congress: Workforce Trends in the Electric Utility Industry" DOE, 2006

31 Community College and University Projects Awarded Grants



Three Subject Areas:

Program Area	#Awards	Total Value
Developing and Enhancing Workforce Training Programs	21	$13,756,289
Strategic Training and Education in Power Systems	11	$27,346,317
Smart Grid Workforce Training Projects	17	$52,552,741
Totals	**49**	**$93,655,347**

Universities play a critical role in grid modernization

- Power Systems Engineering Research Center (PSERC)
  - University collaboration to address challenges facing the electric power industry
  - **ASU, Carnegie Mellon, CO School of Mines, Cornell, Georgia Tech, Howard, Iowa State, Texas A&M, Wash State, Wichita State, UC Berkeley, Univ IL Urb.-Cham, Univ WI-Madison**
- Synchrophasor Engineering Education Program
  - Academic-Industry Collaboration to augment engineering education in process simulation, dynamics, control, and safety
  - **Washington State, NC State, IIT, Univ WY, VA Tech, Texas Tech, Clemson**
- Trustworthy Cyber Infrastructure for the Power Grid (TCIPG)
  - Architecture for End-to-End Resilient, Trustworthy & Real-time Power Grid Cyber Infrastructure
  - **Cornell, University of Illinois, UC Davis, Dartmouth College, Washington State**
- Center for Ultra-Wide-Area Resilient Electric Energy Transmission Networks (CURENT)
  - ERC collaboration with academia, industry, and national laboratories
  - transmission grid that is fully monitored and dynamically controlled in real-time for high efficiency, high reliability, low cost, better accommodate renewables, storage and responsive load.
  - **Univ of Tennessee, Northeastern, RPI, Tuskegee**

2015 Opportunities

- A broad solicitation for University research in Power Systems Engineering is anticipated later this year (PSERC)
- Potential for additional R&D and collaborations with universities focusing on cybersecurity issues for energy delivery in the coming year
- Continued funding of CURENT research
- OE's Advanced Modeling Grid Research FY16 Budget includes $4.4M for expansion of university research in mathematics for power systems, and a competitive solicitation focused on maturing basic research into industry applications to improve operational reliability and security

For more information


Grid Impacts, Benefits, and Lessons Learned

www.smartgrid.gov **provides information on assets deployed, impacts and benefits, lessons learned and analytical methodology**

https://www.smartgrid.gov/recovery_act/publications

Smart Grid Investment Grant Program (SGIG)	**Reports on program progress, technology applications and results, including:** **1. Advanced metering infrastructure - peak and overall energy reduction, and improvements in operational efficiencies of utilities** **2. Distribution automation technologies to improve reliability, system efficiency and operational** **3. Synchrophasor and other technologies in transmission systems to improve reliability and efficiency (via improved operations and asset utilization)** **4. Consumer Bahavior Studies examining customer response to variable rates**
Smart Grid Demonstration Program (SGDP)	**Reports on various topical issues and on the:** **1. Regional Demonstration Projects** **2. Energy Storage Demonstration Projects**
Case Studies	**Project-Specific Documents from SGIG and SGDP Projects**

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