Modernizing the Grid:
Using the Smart Grid to enable integration

Patricia Hoffman

Assistant Secretary, The Office of Electricity Delivery and Energy Reliability
US Department of Energy

4th International Conference on
Integration of Renewable and Distributed Energy Resources
December 6-10, 2010
Albuquerque, NM, USA

Conference Sponsors

EPRI ELECTRIC POWER RESEARCH INSTITUTE
Sandia National Laboratories
Natural Resources Canada
PNM
SEPA solar electric power association

Associate Sponsors

DERlab
NEDO

1) Innovation adds to the wealth of society

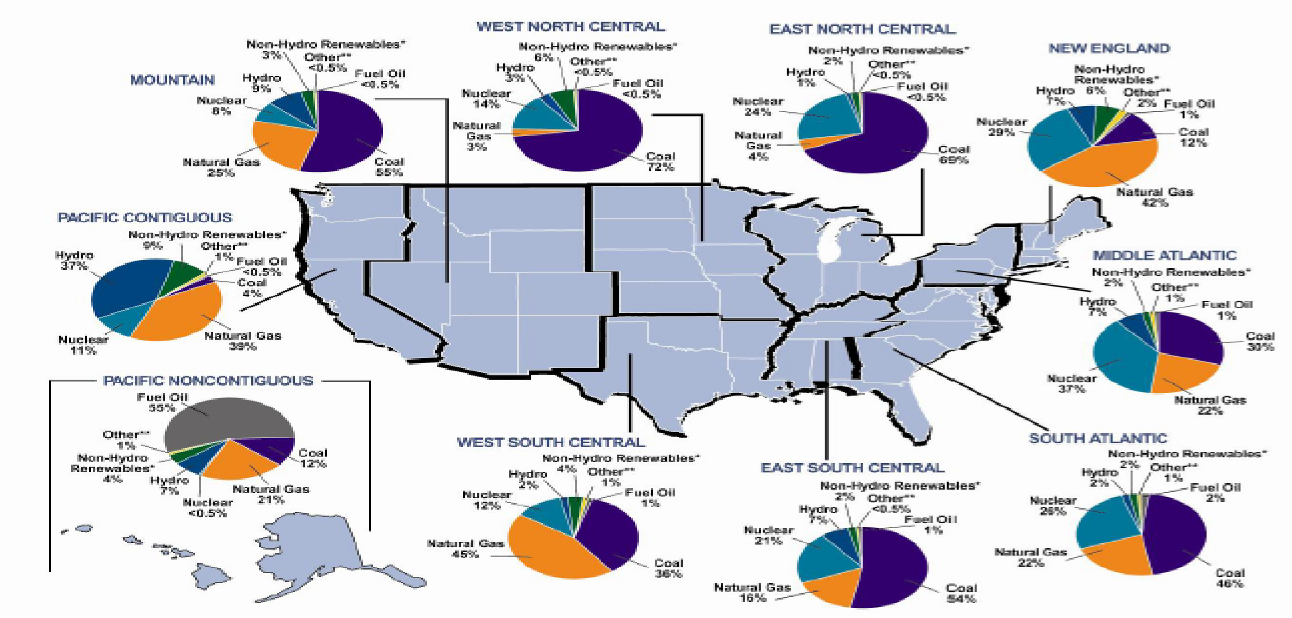
2) Science and technology R&D lie at the heart of innovation

3) Leadership in innovation cannot be taken for granted.

What does the US Grid Look Like?

- Not holistically designed, evolved incrementally in response to local load growth. Today:
  - 30,000 Transmission paths; + 180,000 miles of transmission line
  - 14,000 Transmission substations
  - Distribution grid connects these substations with over 100 million loads
    - residential, industrial, and commercial customers

Different Regions of the Country Use Different Fuel Mixes to Generate Electricity



*Includes generation by agricultural waste, landfill gas recovery, municipal solid waste, wood, geothermal, non-wood waste, wind, and solar.

** Includes generation by tires, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

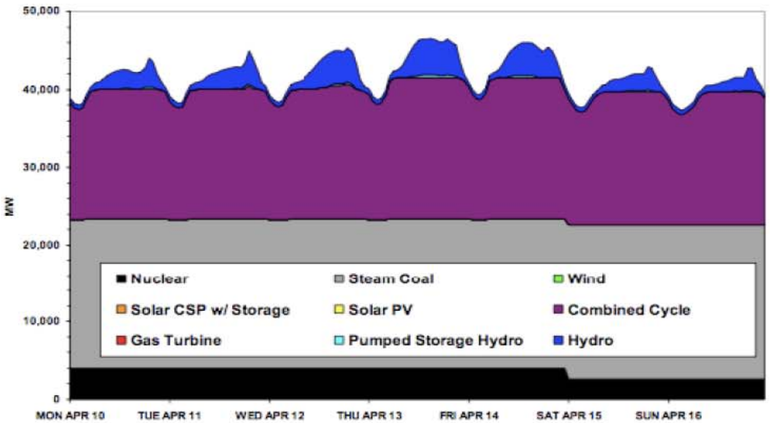
Sum of components may not add to 100% due to independent rounding.

Source: U.S. Department of Energy, Energy Information Administration, Power Plant Operations Report (EIA-923); 2009 preliminary generation data.

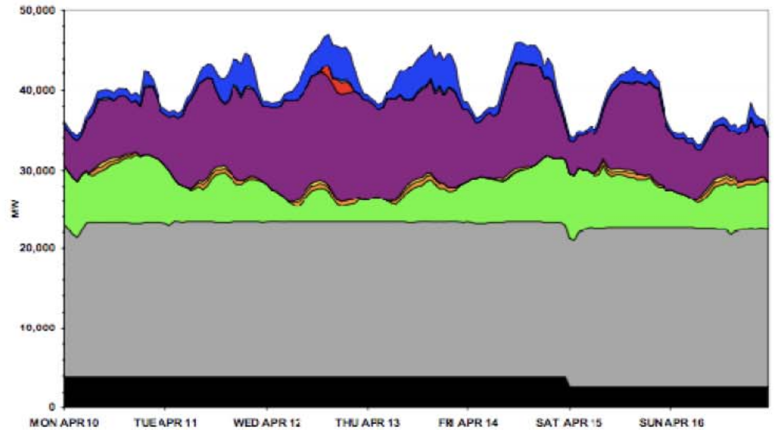
May 2010

Variable Generation Affects Grid Operations

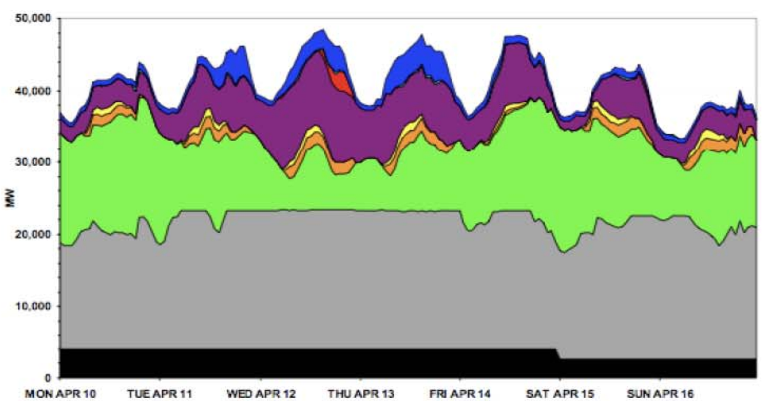
No wind



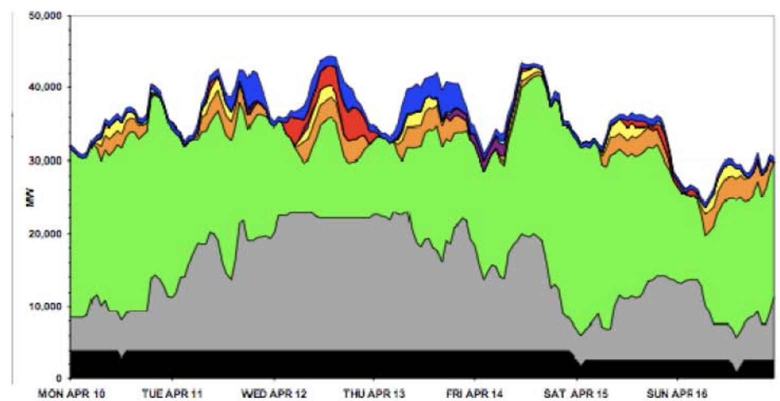
11% renewables



23% renewables



35% renewables

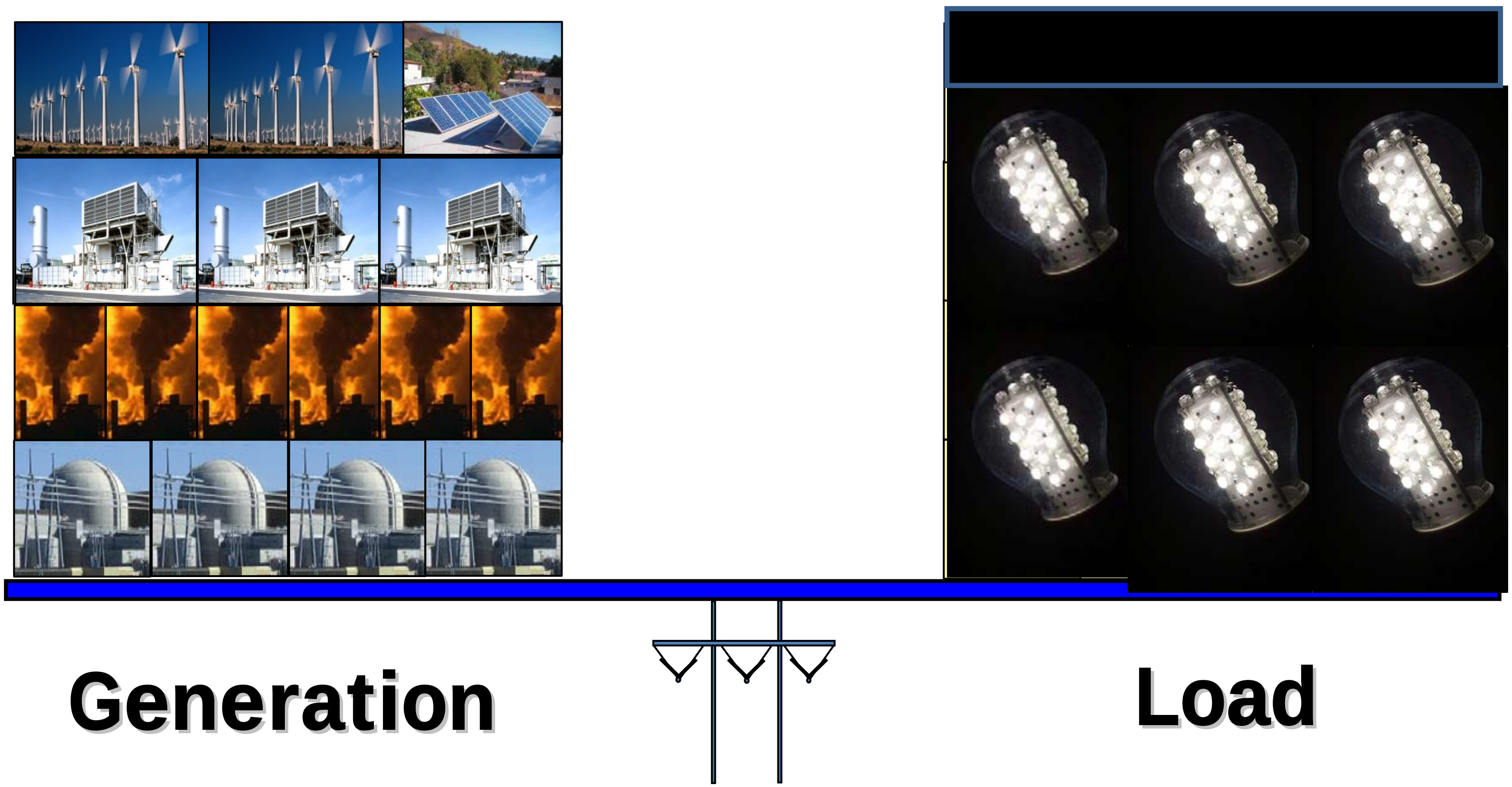


Lew et. al. "How do Wind and Solar Power Affect Grid Operations: The Western Wind and Solar Integration Study". National Renewable Energy Laboratory. (September 2009). p. 6

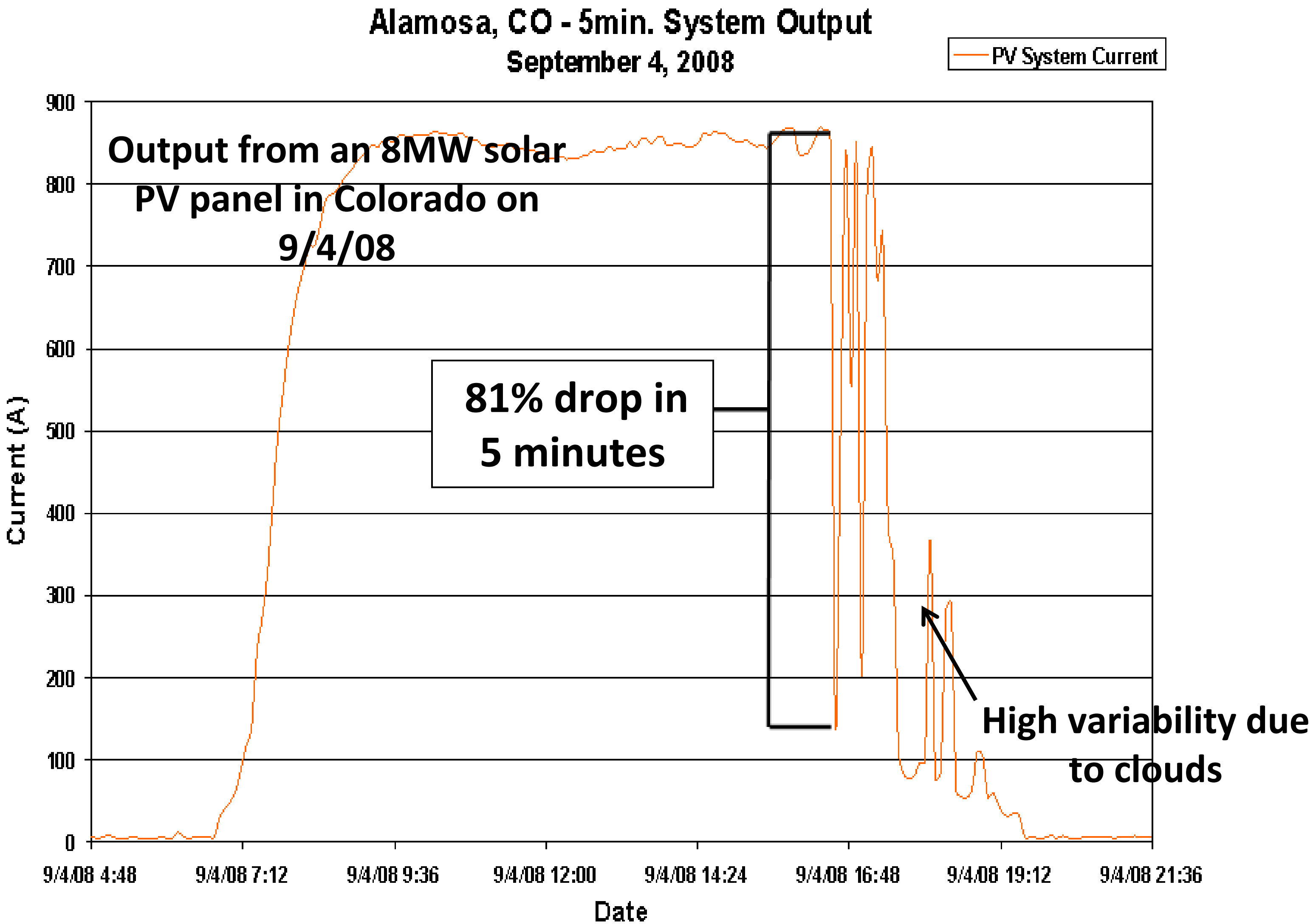
Manage Supply and Demand Differently

Objective

More Dynamic- More Flexible

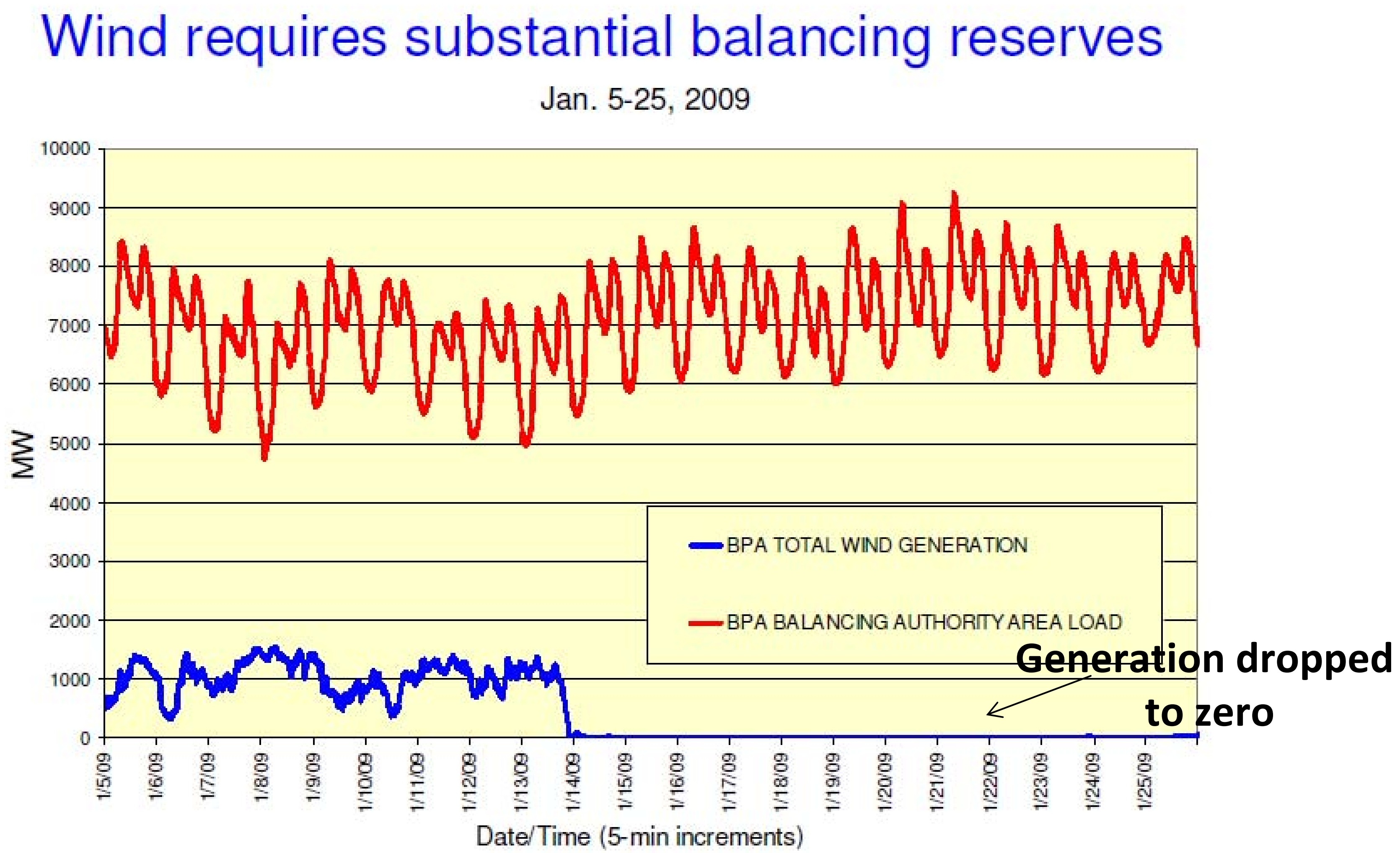


Solar



Alamosa, CO - 5min. System Output
September 4, 2008
PV System Current
Output from an 8MW solar PV panel in Colorado on 9/4/08
81% drop in 5 minutes
High variability due to clouds
Current (A)
900
800
700
600
500
400
300
200
100
0
9/4/08 4:48
9/4/08 7:12
9/4/08 9:36
9/4/08 12:00
9/4/08 14:24
9/4/08 16:48
9/4/08 19:12
9/4/08 21:36
Date

Wind



Wind requires substantial balancing reserves
Jan. 5-25, 2009
MW
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
BPA TOTAL WIND GENERATION
BPA BALANCING AUTHORITY AREA LOAD
1/5/09
1/6/09
1/7/09
1/8/09
1/9/09
1/10/09
1/11/09
1/12/09
1/13/09
1/14/09
1/15/09
1/16/09
1/17/09
1/18/09
1/19/09
1/20/09
1/21/09
1/22/09
1/23/09
1/24/09
1/25/09
Date/Time (5-min increments)
Generation dropped to zero

Priorities

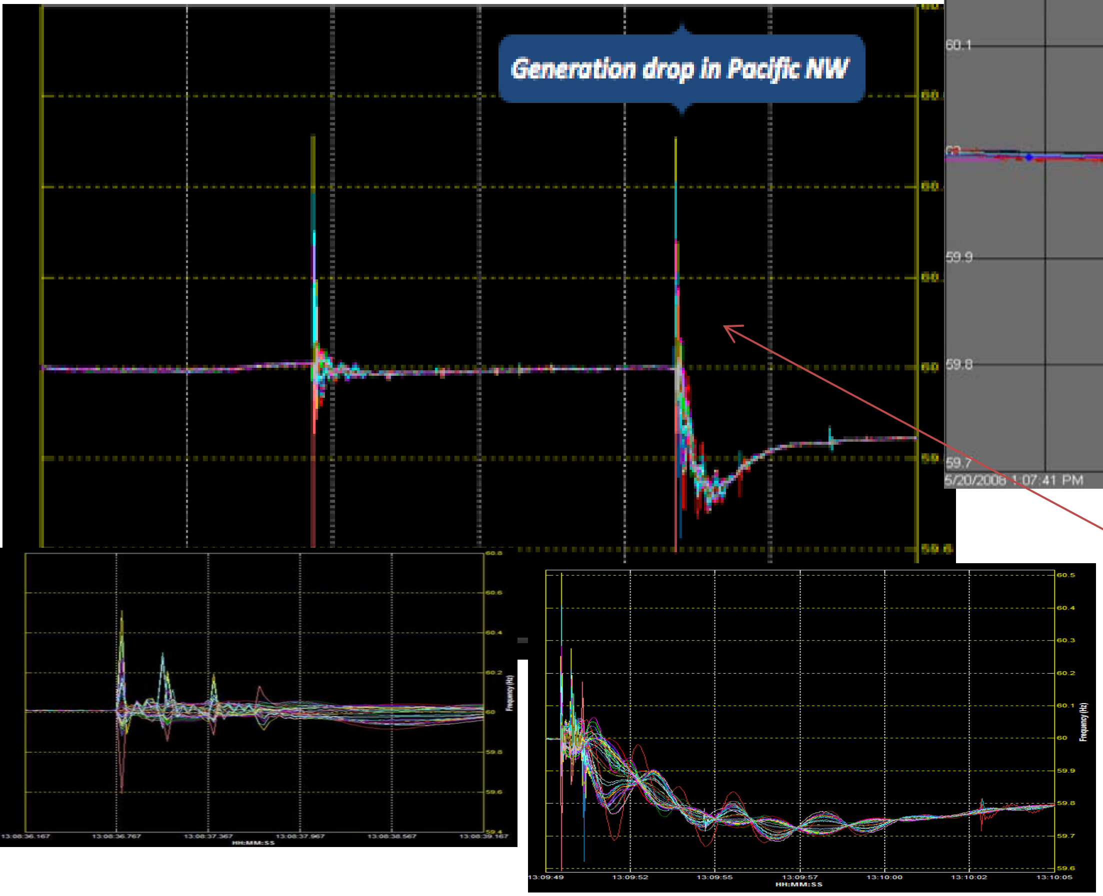
- **Sensors (ability to monitor the health of the system)**
  - Phasor Measurement Units (PMUs)
  - Smart Transformers
  - Smart Meters
  - Dynamic Line Ratings (thermal)
  - Anemometers (wind)/radiance sensors (solar)
- **Modeling/Decision Tools**
  - Smart Grid data sources enable real-time precision in operations and control previously unattainable
  - To integrate high penetrations of renewable energy technologies into the grid, new approaches in power system planning and operation are required
- **Storage (system assessments; cost/benefits analysis)**
- **Innovative Energy Management (Microgrids, layered systems)**

Leveraging international activities – lessons learned.

Why Phasors?

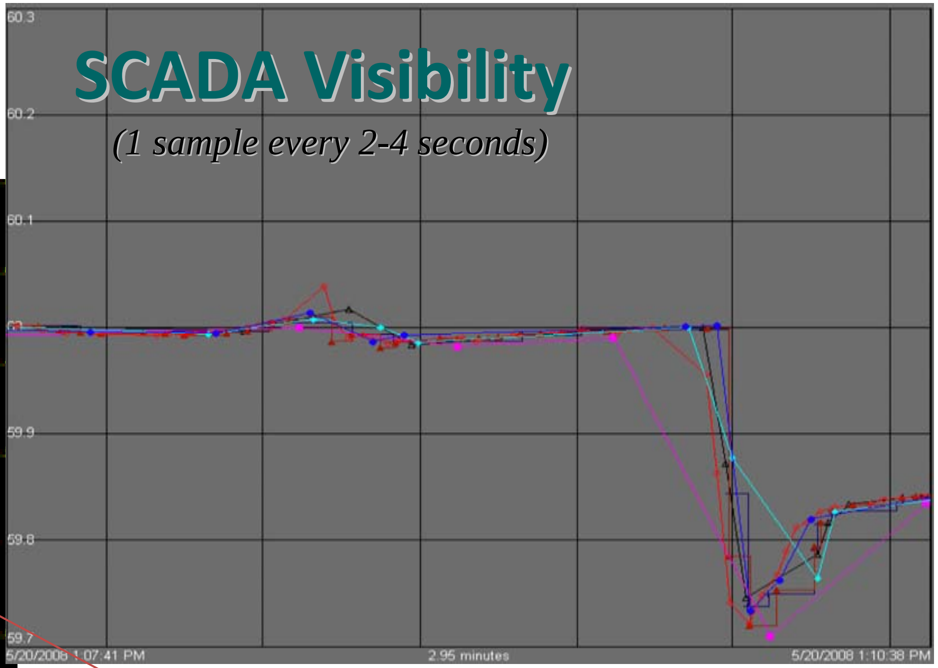
PMU Visibility

(30-60 samples every second)



SCADA Visibility

(1 sample every 2-4 seconds)



2700 MW generation drop & associated oscillations visible

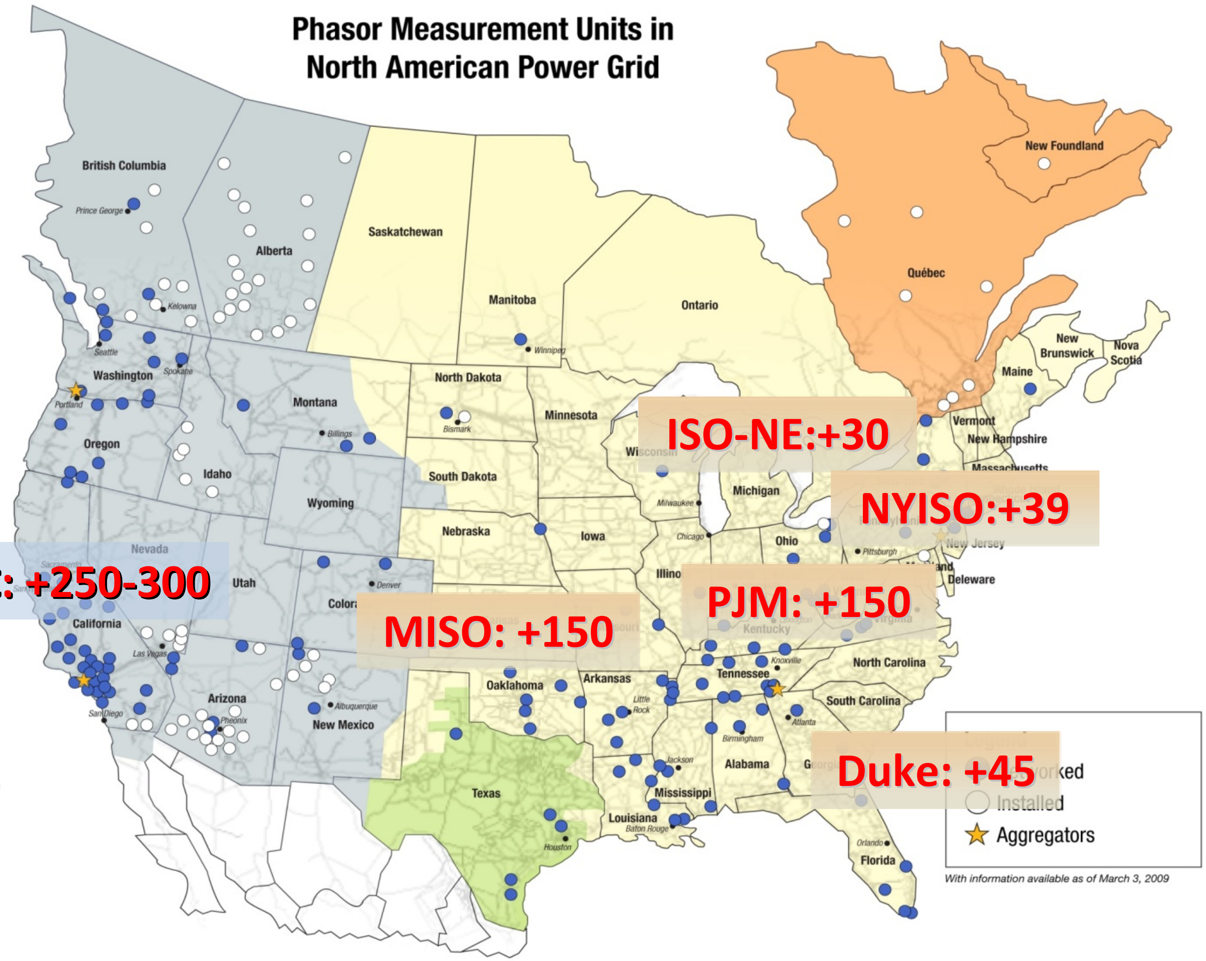
ARRA Smart Grid Investment Grants are providing $~150+M for phasor technologies

Data

Secure access to real-time phasor data; best real-time view of the U.S. electrical system

Knowledge

High-performance computing, mathematics, and visual analytics; use data to understand and predict dynamic grid operations



~ 170 PMUs

Energy Storage Technologies

Energy

- Pumped Hydro
- Compressed Air Energy Storage (CAES)
- Batteries
  - Sodium Sulfur (NaS)
  - Flow Batteries
  - Lead Acid, Lead Carbon
  - Lithium Ion
  - NiMH
  - NiCad
- Flywheels
- Electrochemical Capacitors

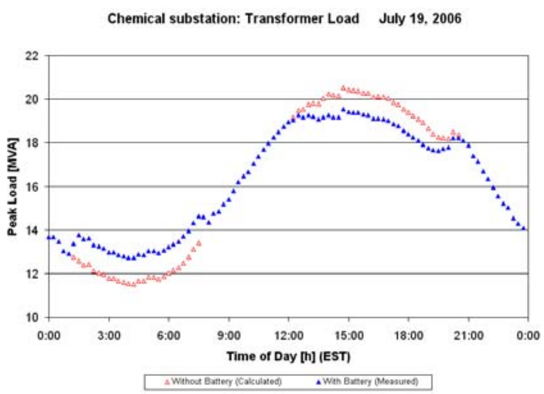
Power

Pumped Hydro (Taum Sauk) 400 MW

Sodium Sulfur Battery 2 MW

Flywheels 1 – 20 MW

OE: Utility Scale Storage on the Grid



Started Operation on June 26th, 2006

APPALACHIAN POWER

A unit of American Electric Power

NGK Insulators Ltd
S&C Electric Co.
DOE / SANDIA

Concept:

Storage defers Upgrade
Opens Possibility for
Regional Islanding, Renewables

First 1MW/6hr in 2007, 3 in 2009
+ Duke, First Energy, PG&E

3x2MW/6hr
In 2009

NaS, Flow batteries,
Lead Carbon

3 ARRA Projects -- 53MW

CERTS Microgrid to Facilitate Integration of Distributed Renewable Electricity Sources

Distinguishing Features

- Seamless islanding and reconnection via single point of common coupling
- Peer-to-peer, autonomous coordination among micro-sources
- Plug-and-play; no custom engineering

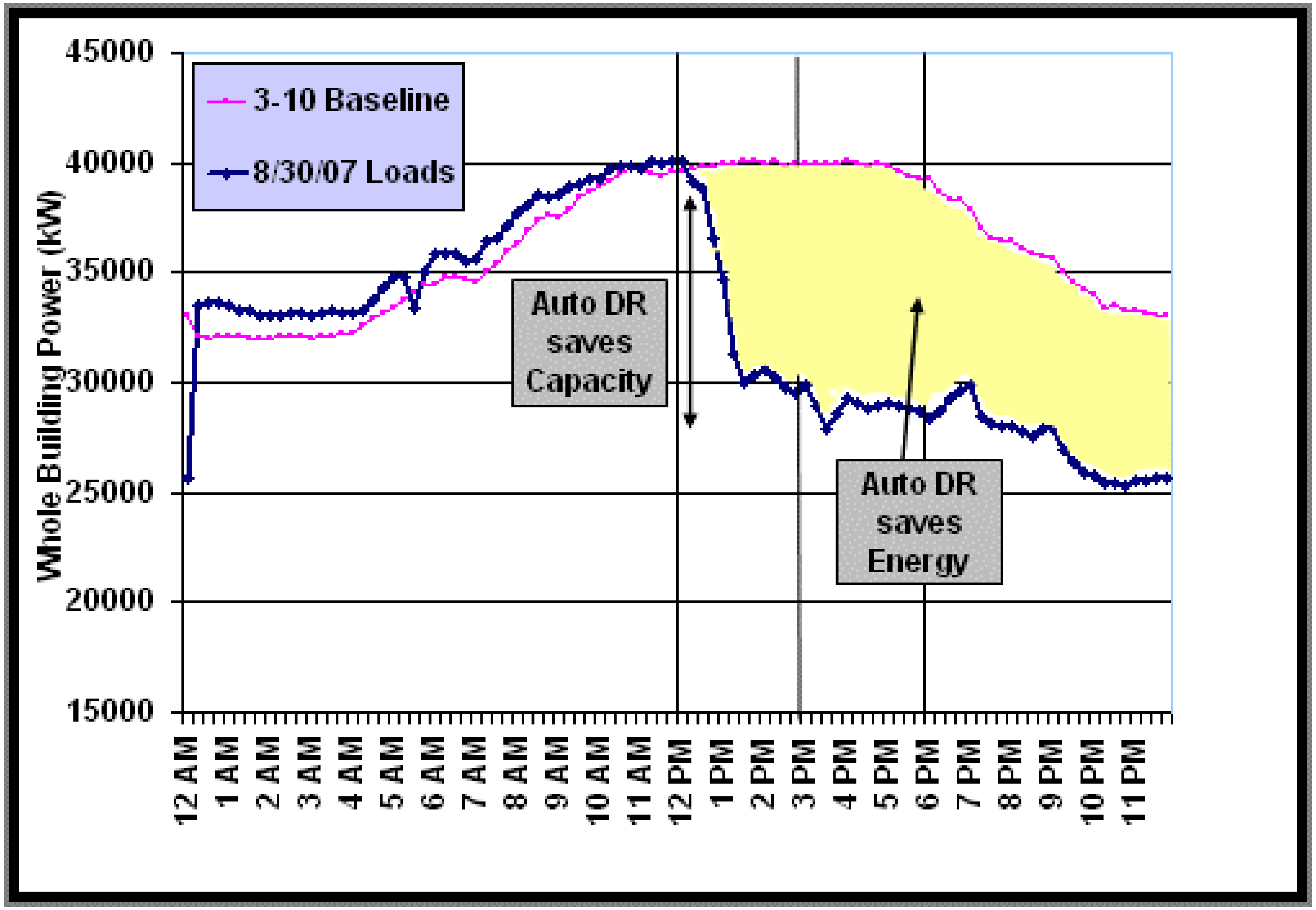
Values

- Customer benefits: bill savings, price certainty, reliability (including power quality), independence
- Grid benefits: a well-behaved electrical "citizen"
- Societal benefits: more resilient local energy infrastructure, possibly also environmental benefits

CERTS Microgrid Test Bed at American Electric Power

Automated Demand Response Saves Capacity and Energy

Electric load profile of Auto DR Participants on 8/30/2007



PG&E

Our ARRA Investments

Smart Grid Systems and Equipment	Numbers of Units (self-reported estimates)	Improvements	Impacts
Networked Phasor Measurement Units	877	• *Near-nationwide coverage* • *6X the 166 existing networked PMUs*	*Enhanced situational awareness and electric system reliability and resiliency*
Smart Transformers	205,983	• *Enables preventative maintenance*	
Automated Substations	671	• *5% of 12,466 transmission and distribution substations in the U.S.*	
Load Control Devices	176,814	• *Enables peak demand reductions*	*1444 MWs of peak demand reduction per year (self-reported estimates)*
Smart Thermostats	170,218	• *Enables peak demand reductions*	
Smart Meters	18,179,912	• *13% of the 142 million customers in the U.S.*	*Transformational changes in consumer behavior and energy consumption*
In-Home Display Units	1,183, 265	• *Enables customer empowerment*	
PHEVs/Charging Stations	12/100	• *Accelerates market entry*	*Begins the path toward energy independence*

Based on DOE /OE ARRA projects

International Efforts

- Clean Energy Dialogue with Canada and Mexico
- Clean Energy Ministerial
  - 10 initiatives will cut energy waste, help deploy smart grid, electric vehicle, and carbon capture technologies, support renewable energy markets; expand access to clean energy resources and jobs, and support women pursuing careers in clean energy.

International Efforts

- International Smart Grid Action Network (ISGAN)
  - To accelerate the development and deployment of smarter electric grids around the world –15 countries and European commission participating to date
- US-EU Energy Council – Technology Working Group
  - Smart Grid Technologies being one of the 10 areas for RD&D cooperation
    - Grid integration of distributed renewable energy sources
    - Demand response and storage
    - Technical standards for smart grids technologies
- DOE-EERA Smart Grid R&D Coordination
  - European Energy Research Alliance Joint Programme (JP) on Smart Grids with 13 research institutions participating from 10 different countries to support achieving 35% of electricity from renewable sources by 2020
  - OE is funding national labs on smart grid projects related to the four sub-programmes of JP on Smart Grids
  - Inaugural DOE/EERA Smart Grid Workshop planned for May 2011 to exchange information on medium- to long-term smart grid R&D