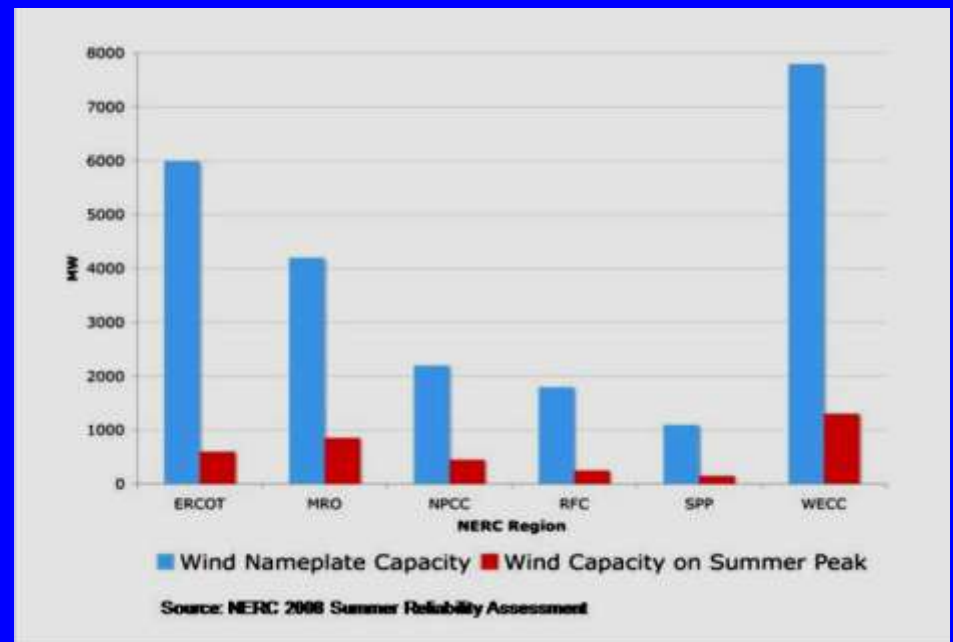
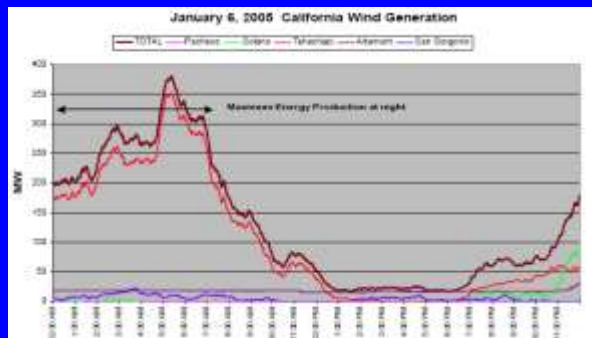


Grid Energy Storage: for Renewables Integration

**IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE**

29 U.S. States have Renewable Portfolio Standards (RPS) Requiring 10-40% Renewables

On Peak Wind
- the Reality!



Cost effective Energy Storage yields better Asset Utilization!

Energy Storage is becoming a Reality!

Some Large Storage Projects

27MW / 7MWh	2003	Fairbanks, AL
34MW / 245MWh	2008	Rokkasho, Japan
20MW / 5MWh	2011	Stephentown, NY
32MW / 8MWh	2011	Laurel Mountain, WV
14MW / 63 MWh	2011	Hebei, China
8MW / 32MWh	2012	Tehachapi, CA
25MW / 75MWh	2013	Modesto, CA

Worldwide (CNESA)

2011 May	370 MW
2011 Aug.	455 MW
2011 Nov.	545 MW
2012 Feb.	580 MW
2012 June	605 MW
2012 Dec.	635 MW



Beacon Flywheels



AES / A123 - Laurel Mountain



SoCal Edison / A123

ARRA Stimulus Funding for Storage Demonstration Projects (\$185M)

DOE Funding: \$185M

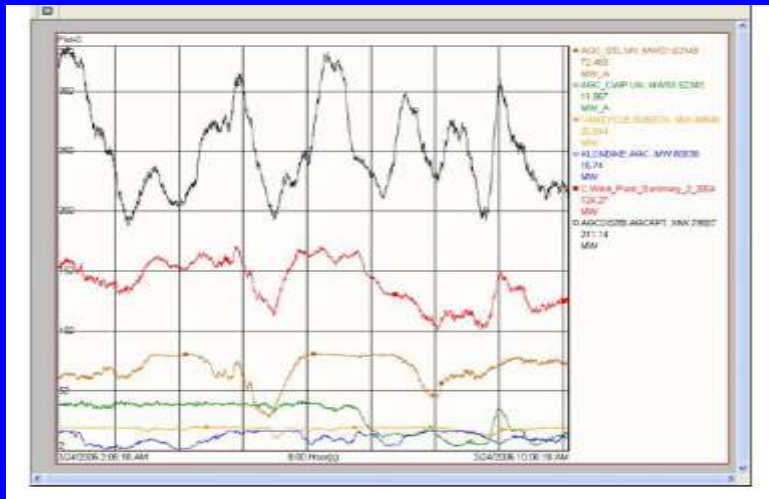
Costshare \$585M!

16 Projects

4 Projects completed

A ten-fold Increase in Power Scale!

Large Batteries for Wind Integration



Coincident BPA Wind Ramps BPA = 777,000 km²
Texas = 696,000 km²



Feb. 24, 2007: 1,500MW / 2.hr; 30x Spotprices

**3 Large Battery + Wind Projects =
53MW in Stimulus Package!**

ARRA – Duke Energy / Xtreme Power

36MW / 40 min battery plant

Ramp control, wind smoothing

Linked to 153MW Wind farm at No-Trees, TX

Construction Completed
Nov. 2012



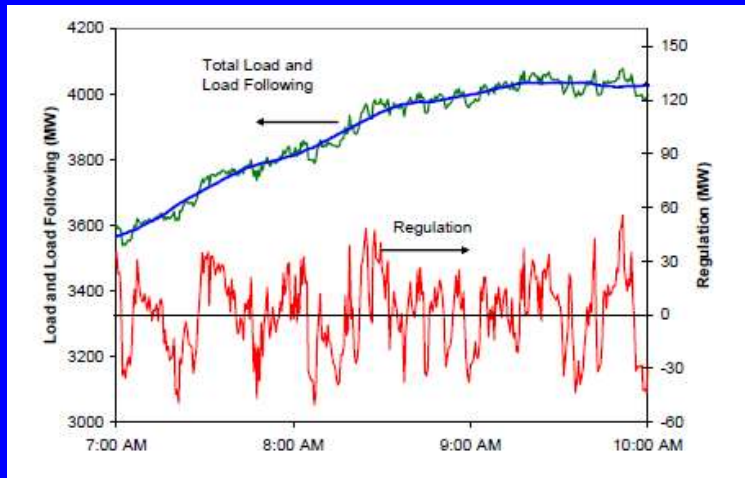
Clean Tech 100 in 2010 / 11

Key Outcomes of 2012 PNNL Study

- ▶ For every 1 MW of extra wind capacity approximately 0.08 - 0.15 MW of intra-hour balancing (minute-to-minute variability) need to be added.

Intra-hour balancing power requirements caused by wind variability in WECC area		
20% wind in WECC	Required MW Storage	Percentage of Installed Wind Capacity
AZ-NM-SNV	174.08	12.8
CA-MX	943.65	14.4
NWPP	1,071.26	11.0
RMPA	504.89	8.0

FREQUENCY REGULATION



DOE Loan Guarantee – Beacon:
20MW Flywheel Storage for
Frequency Regulation in NY-ISO
20MW commissioned July 2011



ARRA Project – 20MW for PJM.
Construction starts Q4 2012

► FERC: PAY FOR PERFORMANCE!

Wind Smoothing and Frequency Regulation

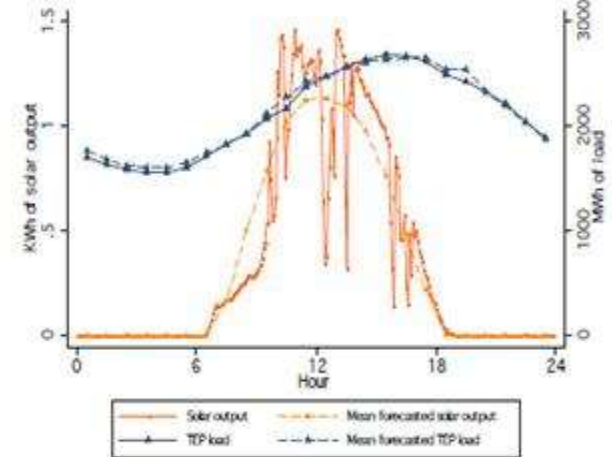


AES / A123 Batteries
Laurel Mountain, WV
32 MW Storage
Footprint <1 acre
no emissions
Integrated with
98MW Wind Farm

Storage with PV:

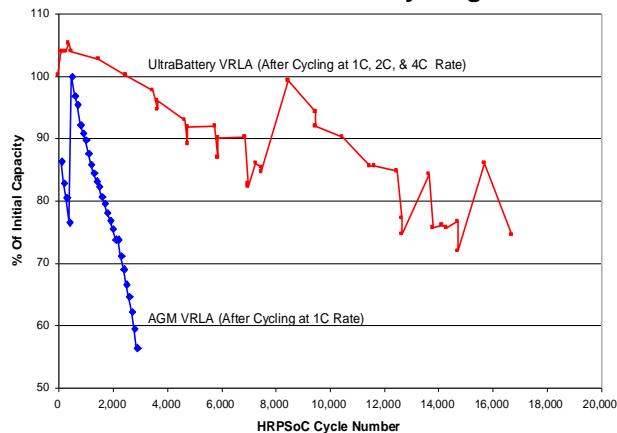
ARRA – Public Service NM:
500kW, 2.5MWh for smoothing of
500kW PV installation; Using
EastPenn Lead-Carbon Technology

Predicted and actual load and solar output, Aug. 15, 2008



Load & PV Output in Tucson, AZ

Ultrabattery And VRLA Battery 1C₁ Capacity After HRPSoC Cycling.



Ultra Battery Testing at Sandia

Commissioned Sep. 24, 2011

Integrator: Ecoult

Hydro Tasmania to install Australia's largest battery on King Island

Installation: Q2 2013

3MW / 1.6MWh

EastPenn Ultrabattery

for renewable integration and a totally green Island!



Integrator: Ecoult



Detroit Edison, ARRA Community Energy Storage Project



20 Units
each 25kW / 2hr
Coupled with 500kW PV
and 500kW / 30min Storage

Monroe, MI, Community College

Backup for Blackouts
Storing Rooftop PV
Fast-charging EV
Aggregated for Ancillary
Services



Dow Kokam Battery

S&C Inverter

Re-Purposed Vehicle Battery Research at ORNL



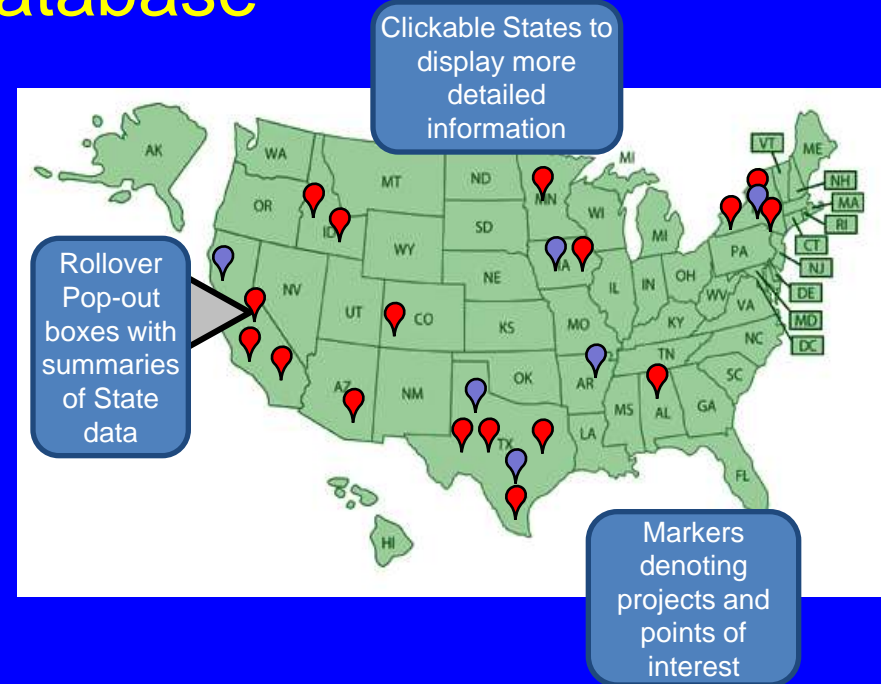
Factory Acceptance Test at ABB Facility Orlando

5 GM Chevy-Volt LiMn batteries in 15 strings
To form 25kW – 50kWh Storage System
To be tested in residential load simulation

Energy Storage Projects Database

A publicly accessible database of energy storage projects In the U.S. and world-wide, as well as state and federal legislation/policies

energystorageexchange.org



DOE/EPRI Energy Storage Handbook

Partnership with EPRI and NRECA to develop a definitive energy storage handbook: Details the current state of commercially available energy storage technologies. Matches applications to technologies. Info on sizing, siting, interconnecting. Includes a cost database

Storage Guidebook for Regulatory Officials

- To inform regulators about Storage benefits
- Provide information on technical aspects of Storage Systems
- Identify regulatory challenges to Storage System deployment
- Suggest possible responses/solutions to challenges
- Provide model PUC submissions for rate base addition
- Advisory Committee of industry and government experts
- sandia.gov/ess/publications/SAND2012-3863.pdf

Collaboration with Clean Energy States Alliance

- Webinar series on Policy Issues and Technical Aspects
- Identify regulatory challenges to deployment
- Develop model PUC submissions requesting approval of rate base addition
- Advisory Committee comprised of industry and government experts

SNL Energy Storage System Analysis Laboratory

Reliable, independent, third party testing and verification of advanced energy technologies from cell to MW scale systems



Milspray Battery under testing



Energy Storage Test Pad (ESTP)

System Testing

- Scalable from 5 KW to 1 MW, 480 VAC, 3 phase
- 1 MW/1 MVAR load bank for either parallel microgrid, or series UPS operations
- Subcycle metering in feeder breakers for system identification and transient analysis
- Can test for both power and energy use
- Redfow Battery being tested currently

For a more Stable Grid

Our Goal is to make

Energy Storage

Ubiquitous!

RESOURCES:

www.sandia.gov/ess

www.electricitystorage.org

ESA Meeting, May 20-22, Santa Clara

EESAT, October 2013, San Diego