

DOCKET

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Progress in Grid Energy Storage

IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE

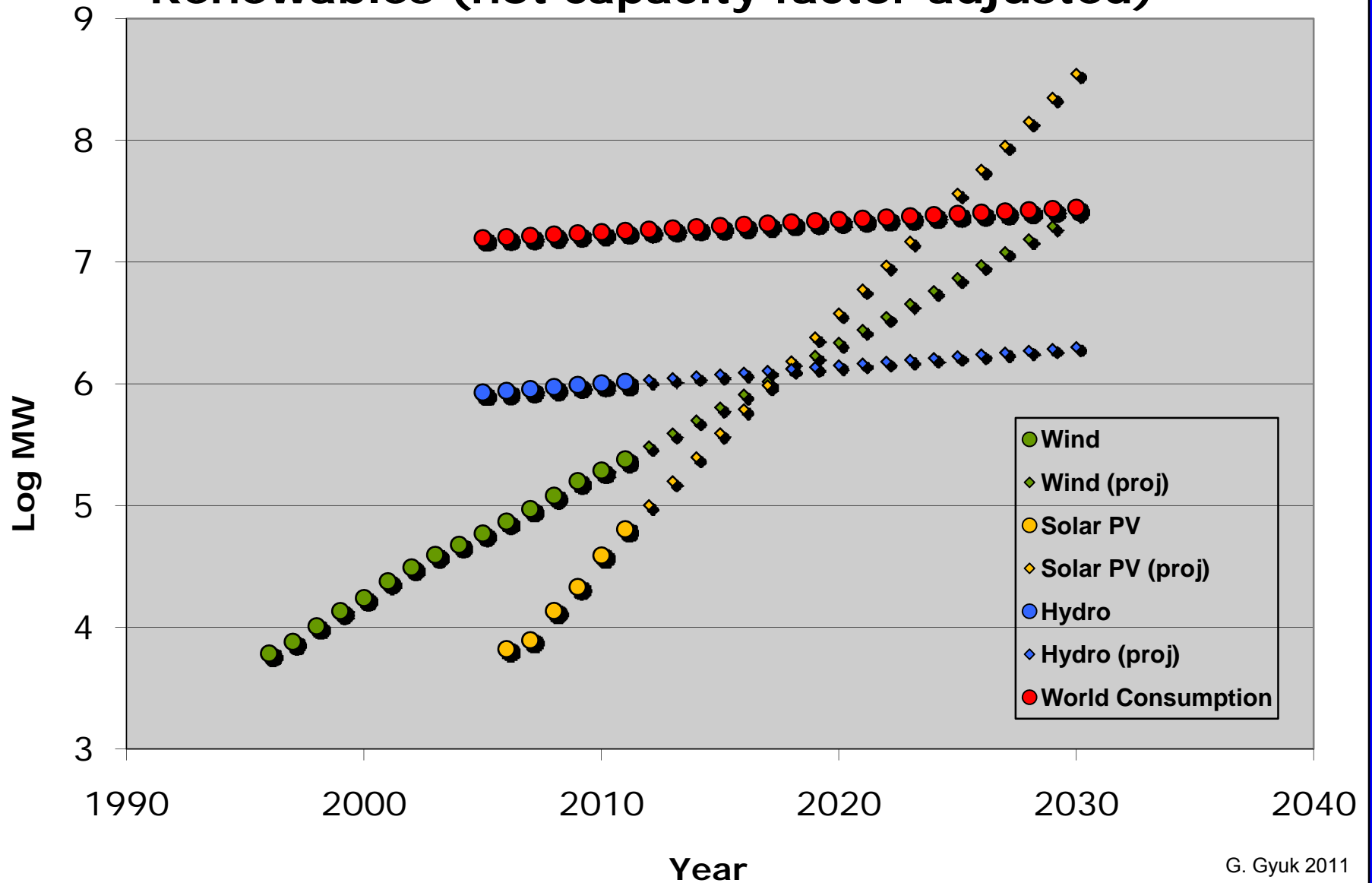
Energy Storage provides Energy

when it is needed

just as Transmission provides Energy

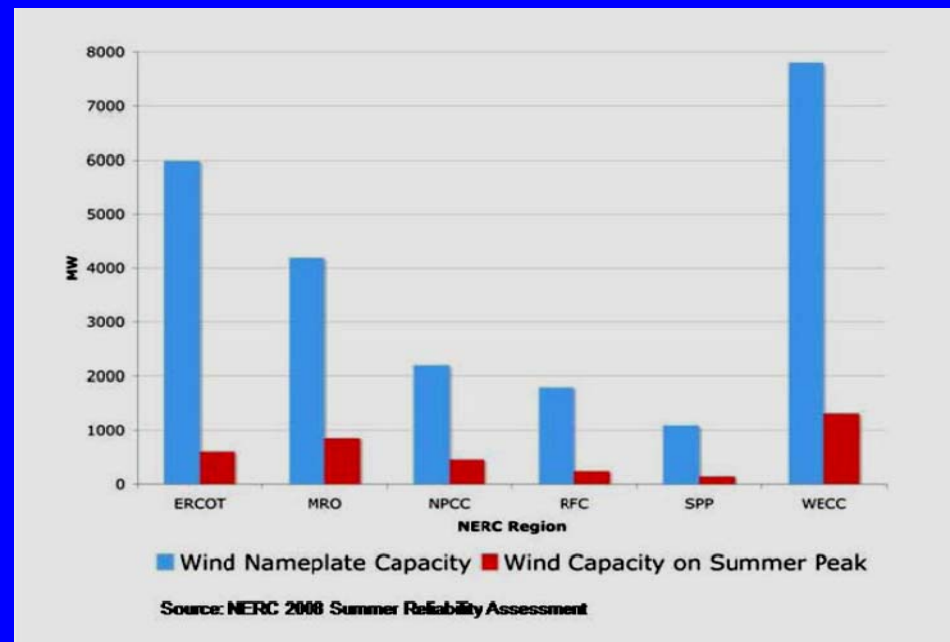
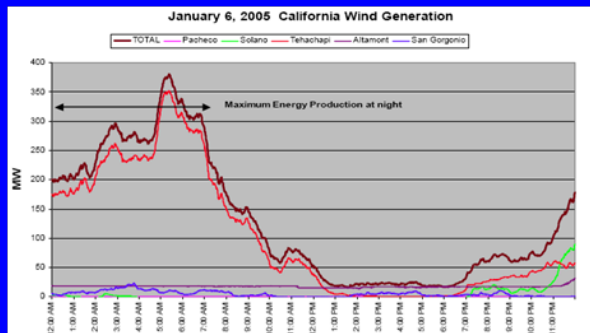
where it is needed

Renewables (not capacity factor adjusted)



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

Some Large Energy Storage Projects:

27MW / 7MWh
34MW / 245MWh
20MW / 5MWh
32MW / 8MWh
14MW / 63 MWh
8MW / 32MWh
25MW / 75MWh

1995 Fairbanks, AL
2008 Rokkasho. Japan
2011 Stephentown, NY
2011 Laurel Mountain, WV
2011 Hebei, China
2012 Tehachapi, CA
2013 Modesto, CA

Worldwide – CNESA

2011 May 370MW
2011 Aug. 455MW
2011 Nov. 545MW
2012 Feb. 580MW
2012 Apr. 590MW

Annual new Deployment

2011 : 121MW
→ 2021 : 2,353MW

(Pike Research)

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

A ten-fold Increase in Power Scale!

Large Battery System (3 projects, 53MW)

Compressed Air (2 projects, 450MW)

Frequency Regulation (20MW)

Distributed Projects (5 projects, 9MW)

Technology Development (5 projects)

533MW - \$585M Costshare!

Legend:

- AGC_STLUR_MW5162148
72.483
MW_A
- AGC_CWP_URL_MW5162343
11.907
MW_A
- VANSYCLE_SUSTN_MW48648
25.044
MW
- KLOANKE_AGC_MW50035
16.74
MW
- VANSYCLE_SUSTN_MW48648
124.20
MW
- DANCOYSTB_AGCRIPT_MW48607
211.14
MW

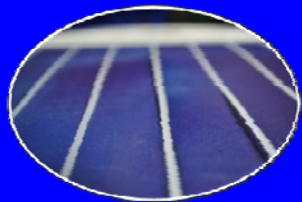
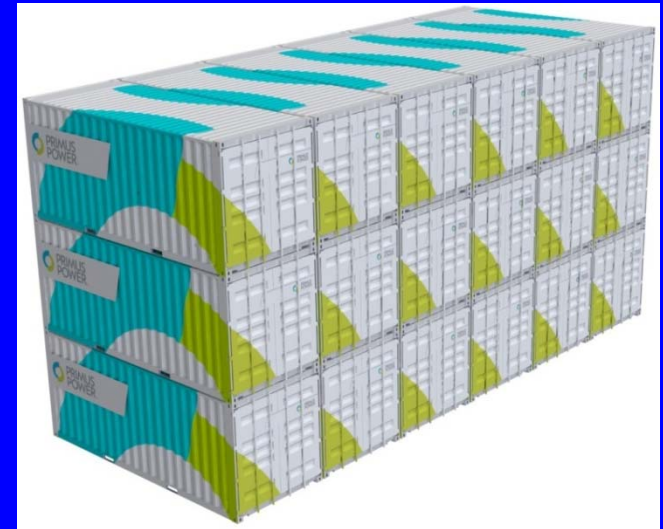
The graph displays the total Texas wind power profile for February 24, 2007. The y-axis represents power in MW, ranging from 0 to 2,500. The x-axis represents time in hh:mm format, from 00:00 to 23:00. Two data series are plotted: a blue line for the 1-minute profile and an orange line for the 1-hour profile. The 1-minute profile shows high variability with frequent peaks and troughs, while the 1-hour profile is a smoothed version of the same data. Both profiles show a significant dip in power around 11:00 and a major peak around 09:00.

Time (hh:mm)	1-min (MW)	1-hour (MW)
00:00	1200	1200
01:00	1150	1150
02:00	1900	1900
03:00	1800	1800
04:00	1850	1850
05:00	1950	1950
06:00	1500	1500
07:00	1600	1600
08:00	1800	1800
09:00	2200	2100
10:00	1500	1500
11:00	600	900
12:00	1000	1000
13:00	1600	1600
14:00	1700	1700
15:00	1800	1800
16:00	1900	1900
17:00	1400	1400
18:00	1100	1100
19:00	900	900
20:00	1100	1100
21:00	800	800
22:00	900	900
23:00	700	700

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

ARRA – Primus Power

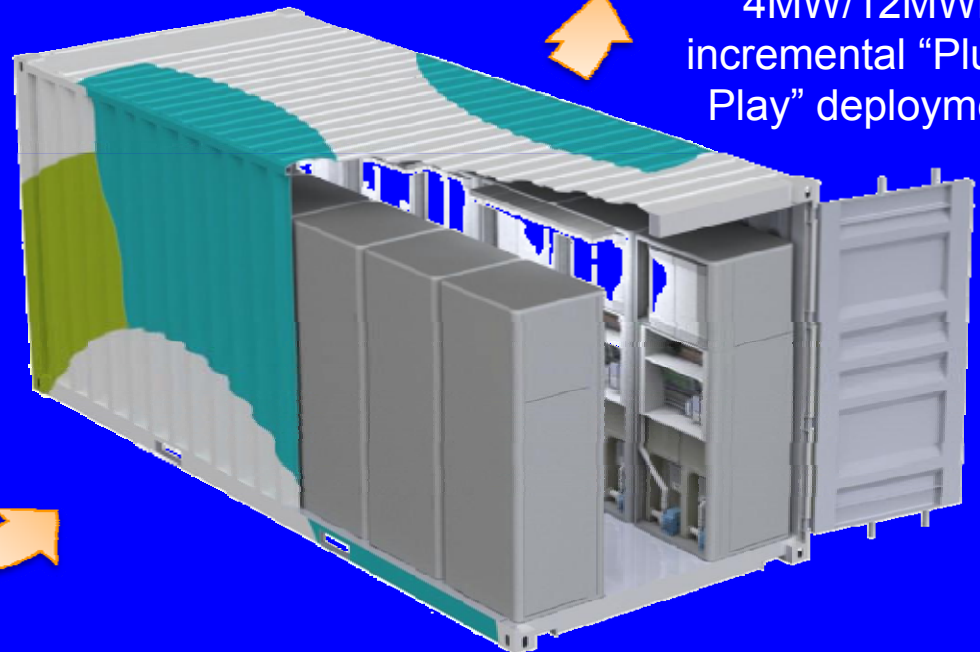
Installing a 25 MW / 3hr battery plant for the Modesto Irrigation District in CA, providing equivalent flex capacity to 50 MW of natural gas engines costing \$73M



High power metal electrodes



Fully self-contained, hermetically sealed flow battery modules



4MW/12MWh incremental "Plug & Play" deployment



250kW/750kWh EnergyPods™

ARRA - Southern California Edison / A123 – Li-Ion:

8 MW / 4 hr battery plant for wind integration at Tehachapi, CA.



A Tehachapi Wind Field

8MW Storage Plant under Construction



ARRA – Duke Energy / Xtreme Power

36MW / 40 min battery plant

Ramp control, wind smoothing

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



Xtreme Power, Kahuku Wind Project

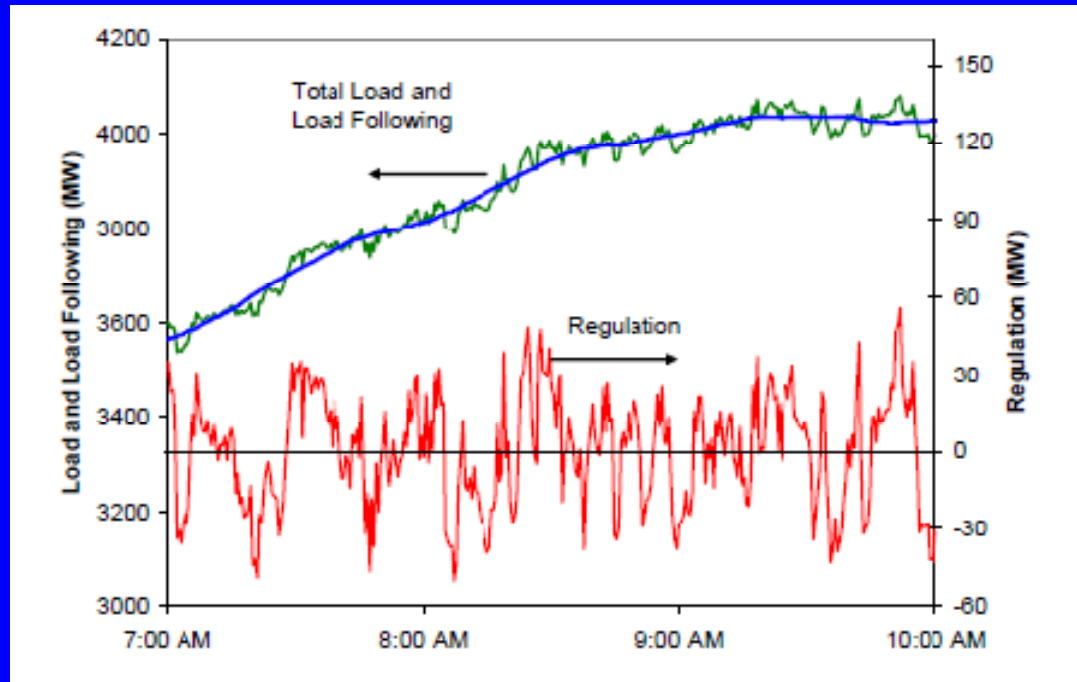
Largest North American Installation with Wind

Location	Oahu, HI
Application	Wind
DPR™	15 MW / 10 MWh
COD	Q1 2011
Services	Ramp Control, Voltage Regulation



This DPR™ will operate on a 30 MW wind farm on the island of Oahu to meet PPA ramp control and smoothing requirements.

Grid Frequency Regulation with Fast Storage: 1 project 20MW



Kirby 2004

Current method to balance constantly shifting load fluctuation is to vary the frequency and periodically adjust generation in response to an ISO signal. Fast storage can respond instantaneously!

Key Outcomes (PNNL Study, 2012)

- ▶ When additional renewables are planned, a certain amount of storage or fast-ramping generation is also needed to firm the variable renewable power.
 - For every unit of wind capacity power, approximately 0.08 to 0.15 units of intra-hour balancing (minute-to-minute variability) need to be added.

Intra-hour balancing power requirements caused by wind variability only				
	MW storage	as a percentage of average demand	as a percentage of peak demand	as a percentage of installed wind capacity
AZ-NM-SNV	174.08	1.0	0.5	12.8
CA-MX	943.65	2.5	1.4	14.4
NWPP	1,071.26	2.1	1.5	11.0
RMPA	504.89	5.6	3.6	8.0

FREQUENCY REGULATION



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

DOE Loan Guarantee – AES / A123:
20MW Lithium Ion Battery for
Frequency Regulation in NY-ISO
8MW on Line!



AES, Laurel Mountain, WV - 32 MW Storage
less than 1 acre, no emissions
Integrated with 98MW Wind Farm



Compressed Air Energy Storage

2 CAES Projects

Inexpensive Off-Peak Power to Compress Air for Storage in Aquifers, Salt Domes, Caverns, or abandoned Gas Wells. On-Peak, Compressed Air is used as Input for Gas Turbine Compressor, increasing Efficiency

McIntosh, Alabama, 1991, 110 MW



Huntorf, Germany, 1978, 290 MW



ARRA – PG&E:

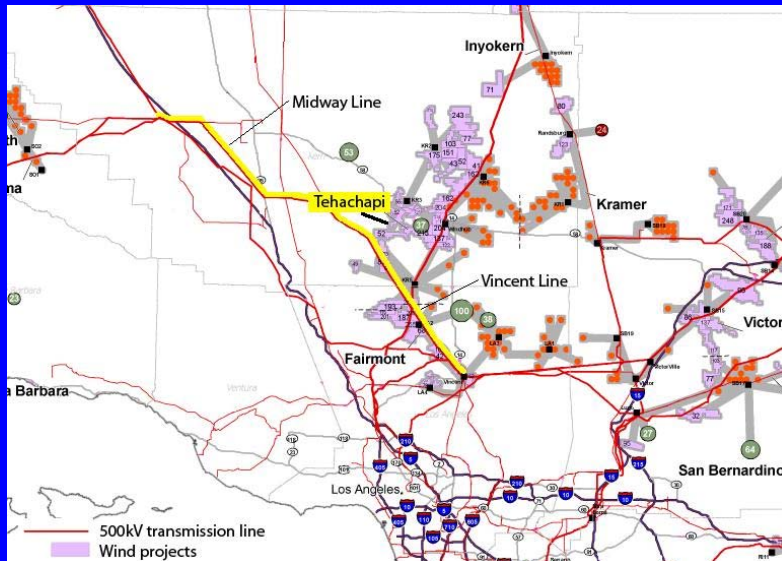
300 MW / 10hr Compressed Air
Energy Storage Facility in
Tehachapi, CA

Depleted Gas Wells

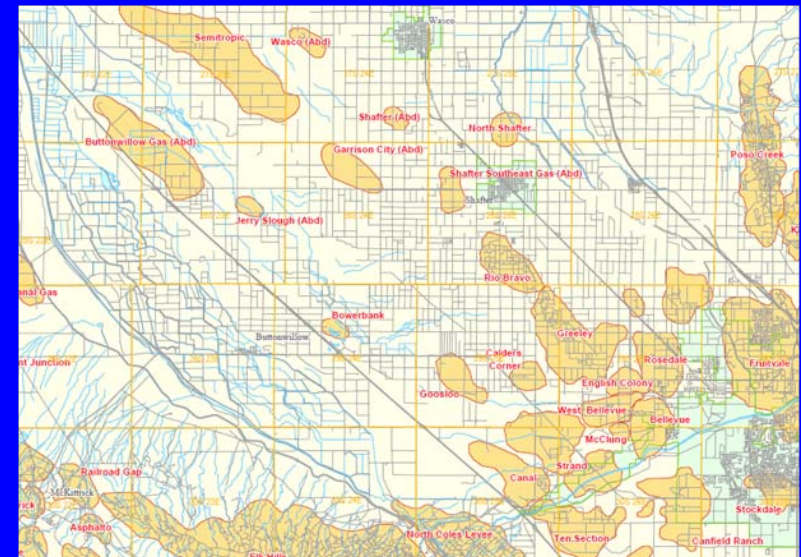
Gas Pipe Line

Existing 500kV Transmission Line

4 500 MW New Wind in 4-5 Years



Location of Wind Resources



Location of Depleted Gas Fields

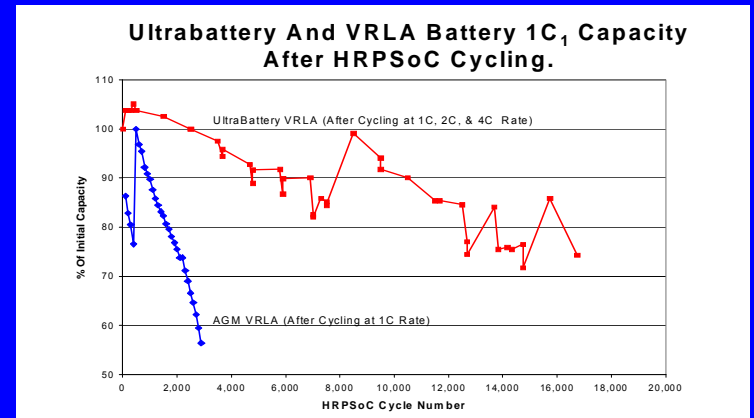
ARRA – Public Service NM: 500kW, 2.5MWh for smoothing of 500kW PV installation; Using EastPenn Lead-Carbon Technology



Commissioned Sep. 24, 2011

Integrator: Ecoult

Commissioning June 2012



PbC Testing at Sandia

ARRA – EastPenn, PA: 3MW Frequency Reg for PJM 1MW 1-4hrs Load Management during Peak Periods

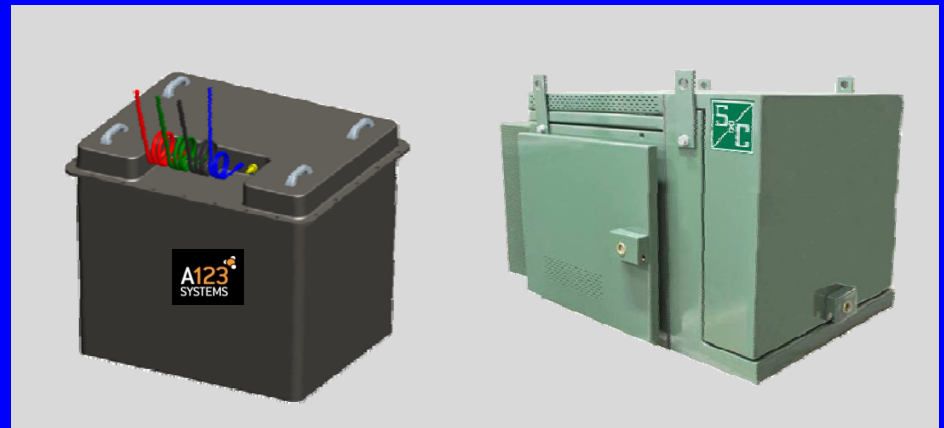


Detroit Edison, ARRA Community Energy Storage Project

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



Monrovia County
Community College



Dow Kokam Battery

S&C Inverter

ARRA - Enervault:

250kW/4hr Fe-Cr Flow Battery for PV

PV: 300 kW

Storage: 250 KW

Peak output: 450kW

Storage Cost: +16%

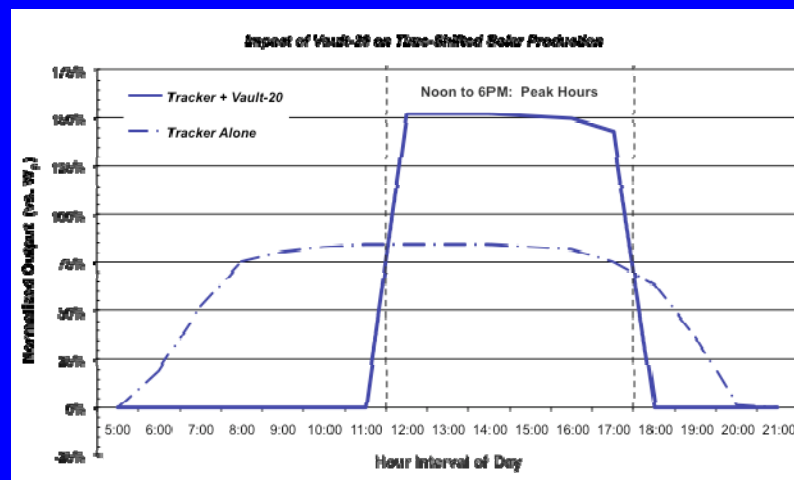
Storage Value: +84%



Tracking PV in Almond Grove



Flow Battery Prototype



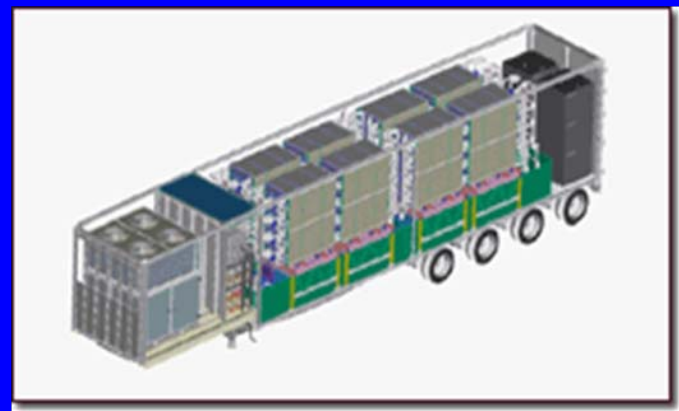
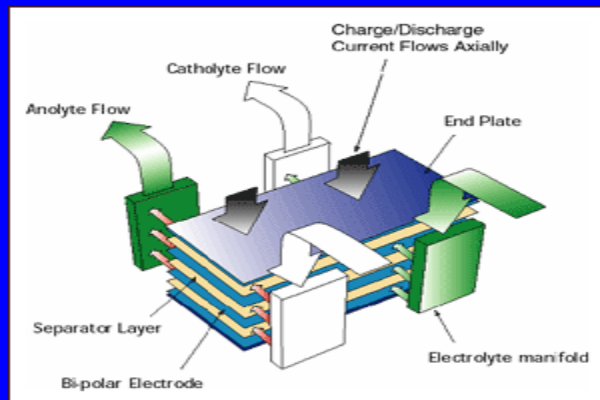
Leveraging PV with Storage

ARRA Distributed Project:



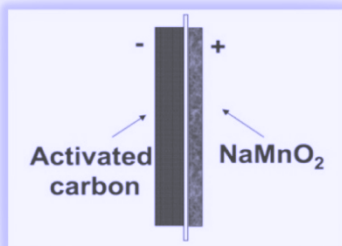
Installation of 5 Transflow 2000 500kW
ZnBr Battery Systems at locations within
SMUD and National Grid Utility Districts:

- 2 units at a substation in Syracuse
- 1 unit at Syracuse University
- 1 unit at SMUD HQ microgrid
- 1 unit at SMUD Solar Smart Homes Project

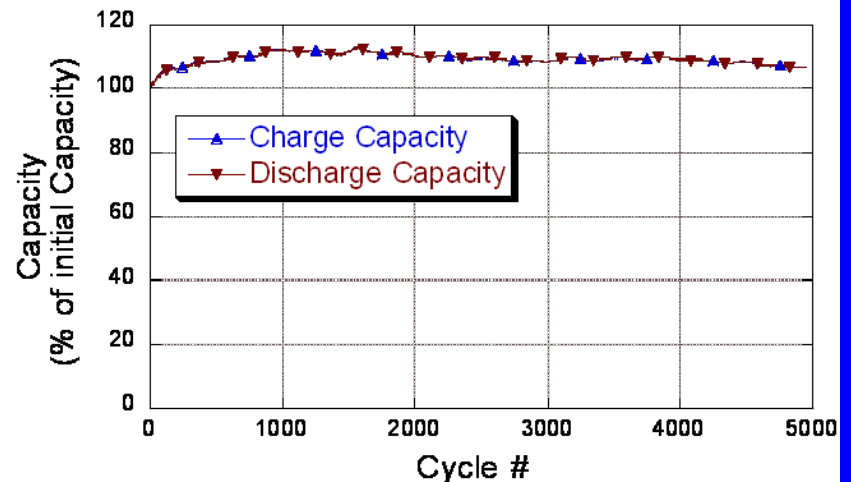


ARRA - Aquion Energy: Aqueous Sodium Ion Battery

Winner, 2010
World Technology Award



- Cost Goal: <\$200/kWh
- Lifetime cost: <\$0.10/kWh
- Ubiquitous, low cost precursors
- Inexpensive manufacture
- Roundtrip Efficiency >85%
- 5000 cycles demonstrated



ARRA - SustainX:

Totally green Isothermal CAES

Awards: GE Ecomagination,
Clean Tech 100 in 2010 / 11



A site-anywhere solution – eliminates lengthy siting and risk associated with geologic storage

Superior thermodynamics – eliminates reliance on natural gas

Isothermal efficiency of 95% compared with 54% for adiabatic technique

Higher pressure and efficiency make pipe-type storage cost effective

A patented and demonstrated, low-cost, long lifetime **energy** storage solution

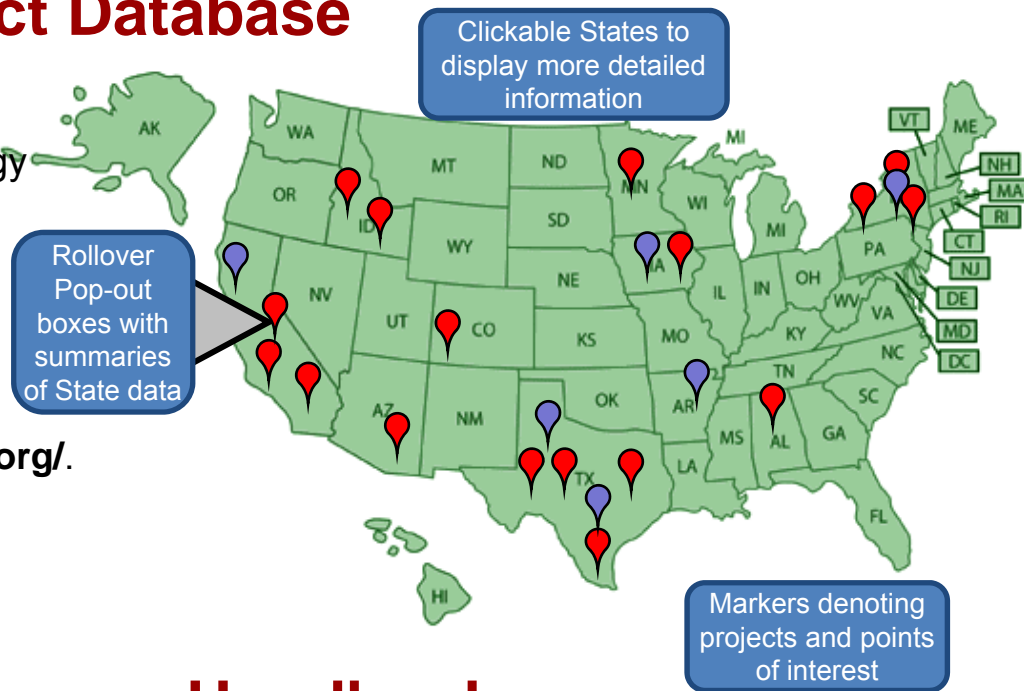




Energy Storage Project Database

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

<http://www.energystorageexchange.org/>.



DOE/EPRI Energy Storage Handbook

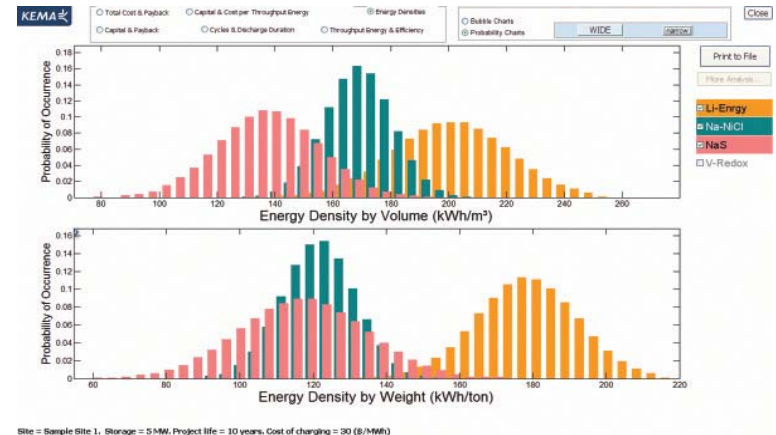
Partnership with EPRI and NRECA to develop a definitive energy storage handbook:

- Details the current state of commercially available energy storage technologies.
- Matches applications to technologies
- Info on sizing, siting, interconnecting
- Includes a cost database



ES-Select: Energy Storage Selection Tool

- A tool for high-level decision makers to facilitate planning for ESS infrastructure:
 - High-level technical and economic review of storage technologies
 - Determine and size applicable energy storage resources
 - Develop a preliminary business case
- Educate potential owners, electric system stakeholders and the general public on energy storage technologies
- Developed by KEMA
- <http://www.sandia.gov/ess/esselect.html>



Storage Guidebook for Regulatory Officials

- Inform regulators about Storage benefits
- Provide information on technical aspects of Energy Storage Systems
- Identify regulatory challenges to increased Storage System deployment
- Suggest possible responses/solutions to challenges
- Develop model PUC submissions requesting approval of rate base addition
- Advisory Committee comprised of industry and government experts



Development of a Protocol to Measure and Report Performance of Energy Storage technology

- We need a common language for technology providers and prospective users
- No uniform acceptable criteria exist for comparable statements of performance
- This causes confusion in the market and adversely affects technology acceptance
- DOE is leading an effort to develop an initial protocol (pre-standard)
 - Formation of representative stakeholder group
 - Clarification of anticipated application and use of the protocol by industry
 - Develop a pre-standard with reasonable consensus
 - Ongoing support as technology evolves

Collaboration with Clean Energy States Alliance

- Webinar Series on Policy Issues related to Energy Storage
- Provide information on technical aspects of Energy Storage Systems
- Identify regulatory challenges to increased Storage System deployment
- Suggest possible responses/solutions to challenges
- 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

Expertise to design test plans for technologies and their potential applications

Cell, Battery and Module Testing

- Testers to accommodate a wide range of testing applications including:
 - 14 channels from 36 V, 25 A to 72 V, 1000 A for battery to module-scale tests
 - Over 125 channels; 0 V to 10 V, 3 A to 100+ A for cell tests



72 V 1000 A Bitrode (2 Parallel Channels)



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 cases

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DOE Energy Storage Program

Aggressively Furthers

Market Pull and Technology Push:

Demonstrations and Research

