

# Progress in Electrical Energy Storage

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ENERGY STORAGE RESEARCH, DOE

Energy Storage provides Energy

**when** it is needed

just as Transmission provides Energy

**where** it is needed

## **Transmission**

**links Generation and Consumer  
in Space**

## **Storage**

**links Generation and Consumer  
in Time**

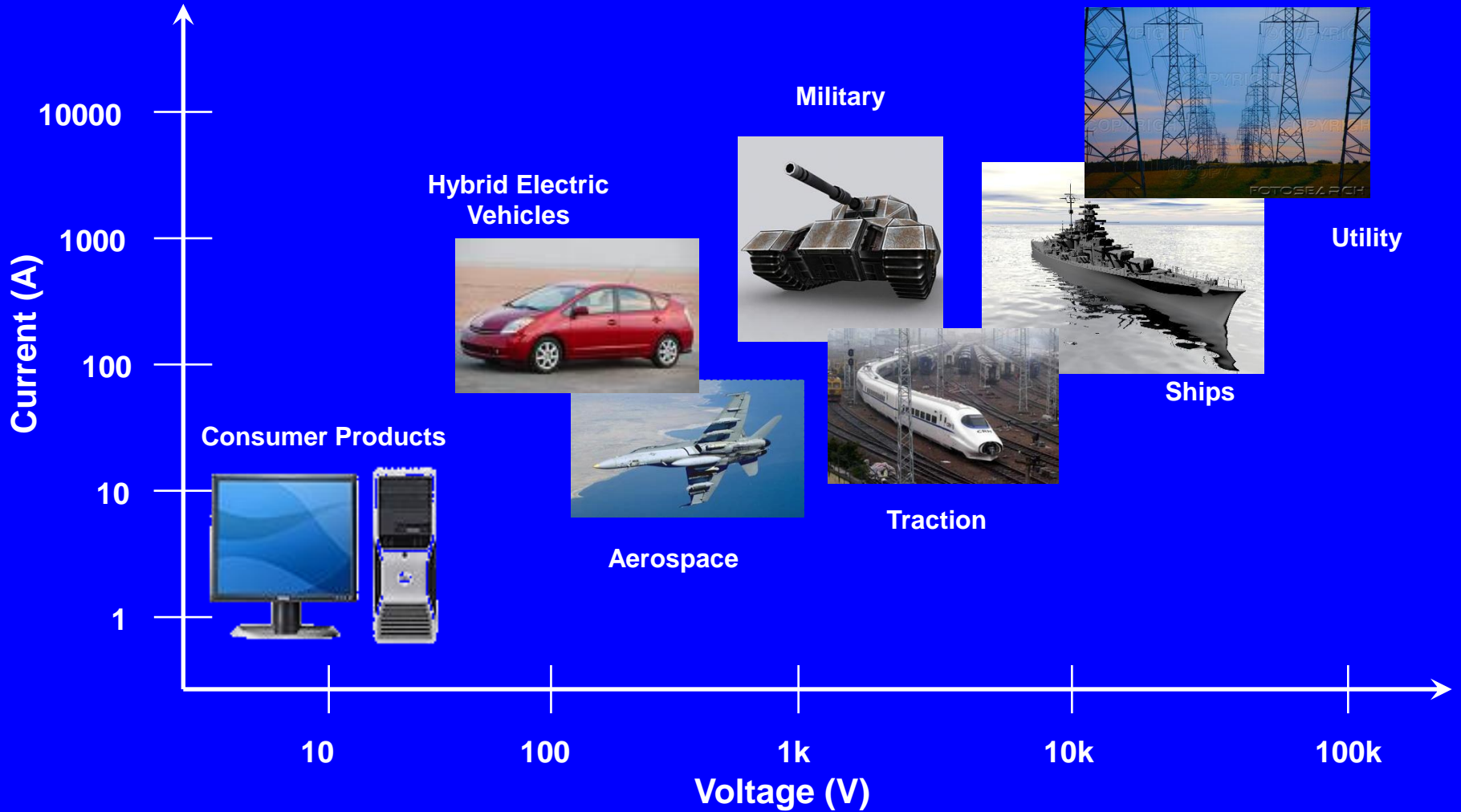
Load and Generation must be balanced on the Grid. Traditionally, Generation was Controlled while the Load was variable.

With Increasing Renewable Penetration Generation has also become variable.

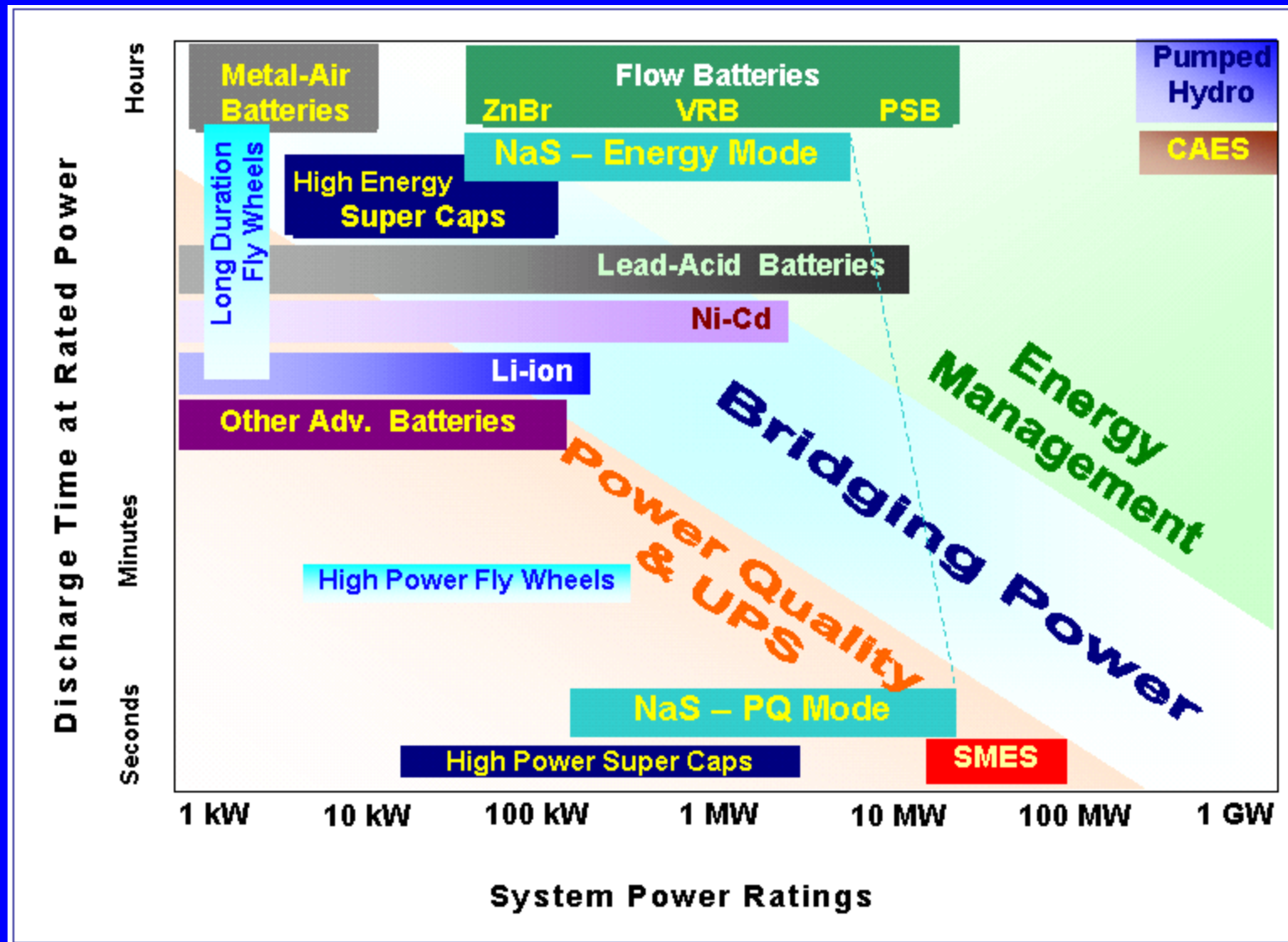
Penetration of Electric Vehicle use inserts a new, and as yet unknown variable

Storage offers a Buffer on all Levels of the Grid

# Scales of Power



# Storage Technologies and Regimes of Application



# 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)

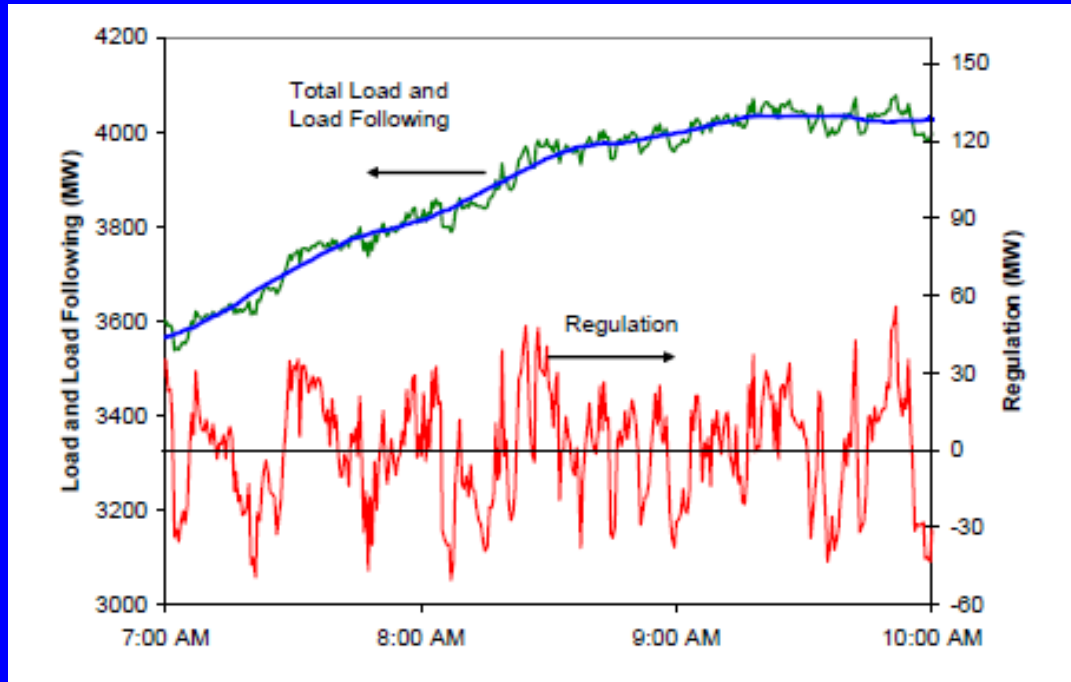
533MW - \$585M Costshare!

# **VOLTAGE and FREQUENCY REGULATION**

*Market ready*



# Grid Frequency Regulation with Fast Storage:



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!



## 2x 100kW/15 min Flywheel system Demos

CEC / DOE and NYSERDA / DOE

Regulation by fast storage  
may be twice as effective  
as gas turbines  
(Y. Makarov, PNNL, )

Flywheels yield a 70-80%  
Reduction in CO2 emission  
over present methods  
(Fioravanti, KEMA, 2007)

For 20% wind in CA , Frequency  
Regulation needs will double  
CAISO



2 x 1MW / 15 min Flywheels  
in NE-ISO



4 x 1MW / 15min Li-Ion  
in PJM. CA-ISO

**FERC Order 890, requires ISOs to develop tariffs,  
market rule, and control algorithms, to open markets  
for new technologies to provide ancillary services**

# ARRA - Beacon Power: 20MW Flywheel Storage for Frequency Regulation in PJM



Coming: Pay for Performance!



**DOE Loan Guarantee – Beacon:**  
20MW Flywheel Storage for  
Frequency Regulation in PJM  
8MW on Line!

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

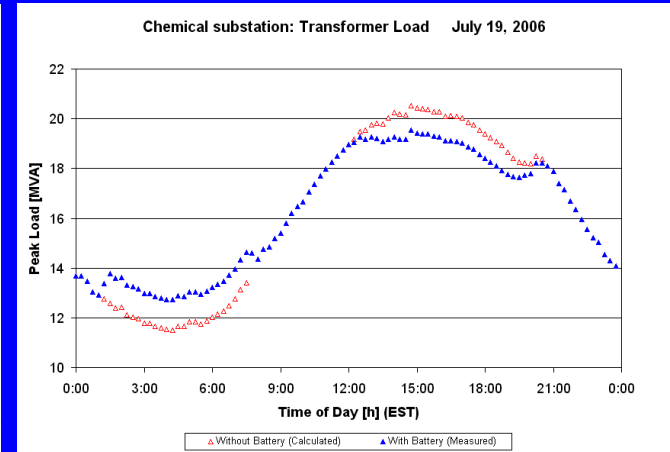


**PEAK SHAVING**

**ENERGY MANAGEMENT**

**UPGRADE DEFERRAL**

*Near commercial*



Charleston, WV Appalachian Power Substation – AEP / DOE Project, June 2006

# 1.2 MW / 6hr NaS Battery for Substation Support



3 x 2MW for Substation Support,  
and Reliability during 2009



# Distributed Energy Storage Projects

Vanadium Redox: City of Painsville, OH

Load leveling for 32MW coal plant; 1MW, 6-8MWh

Lithium Ion, Edison Electric, A123

Community Energy Storage; 20units @ 25kW, 50kWh

Lead/Carbon, EastPenn

Frequency regulation, Peak shifting; 3MW, 1-4MWh

Lead/Carbon, Public Service New Mexico

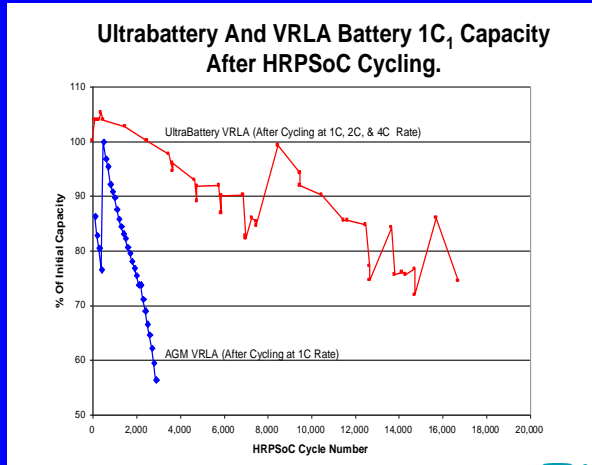
Smoothing of 500MW PV installation; 500kW, 2.5MWh

ZnBr, Premium Power

Peak shaving; 5 systems @ 500kW, 2.5MWh

# ARRA - East Penn:

3MW Frequency Regulation + 1MW / 1hr Demand Management  
Using new Lead-Carbon Technology



Battery Stacks

Testing at Sandia



New >200MW East Penn  
Battery Manufacturing  
Plant at Lyon Station, PA

5 Distributed Projects = 9MW in Stimulus Package



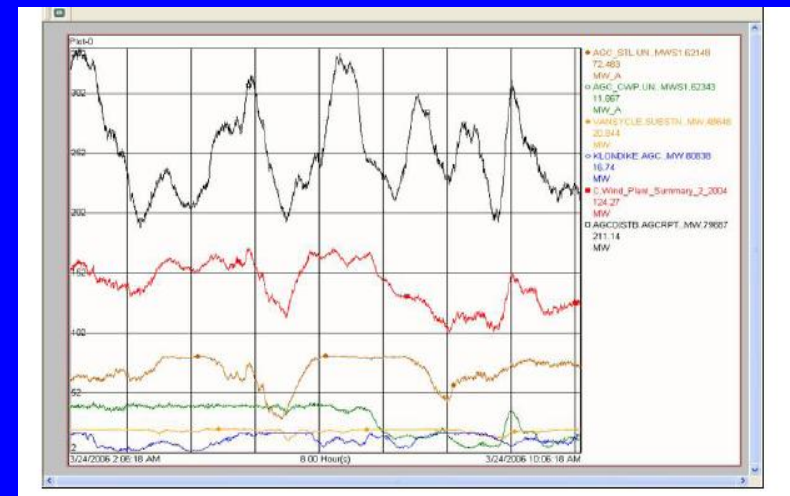
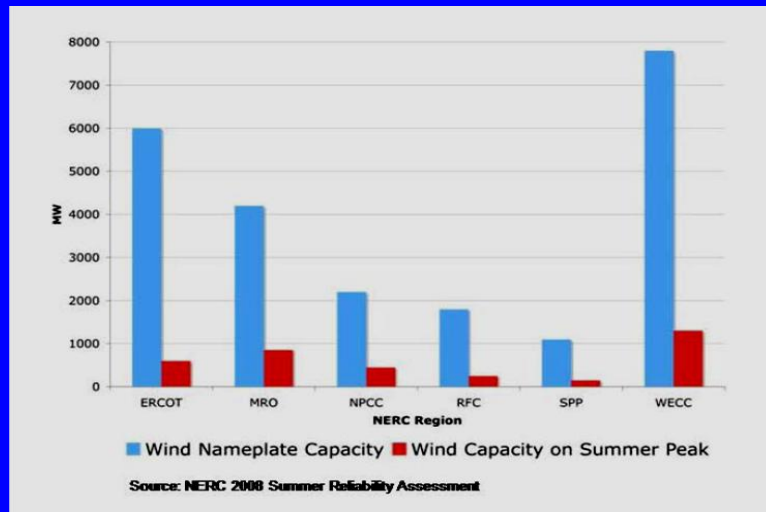
**RENEWABLES DISPATCH**

**SMOOTHING, RAMPING,**

**and PEAK SHIFTING**

*increasingly considered*

# Large Batteries for Wind Integration



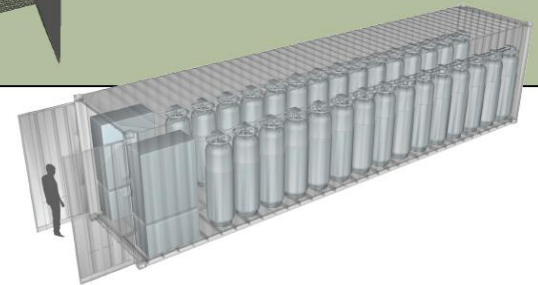
3 Large Battery + Wind Projects =  
53MW in Stimulus Package!

## ARRA- Primus Power:

25MW / 3hr battery plant for the Modesto, CA Irrigation District,  
firming 50MW of Wind, replacing \$75M of Gas fired Generation.



Totally sealed battery module  
With a ZnCl electrolyte and  
zinc and graphite electrodes



**PRIMUS  
POWER**

Primus Power Corporation  
2450 Mariner Square Loop  
Alameda, CA 94501

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

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



# Compressed Air Energy Storage CAES

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

McIntosh, Alabama, 110 MW



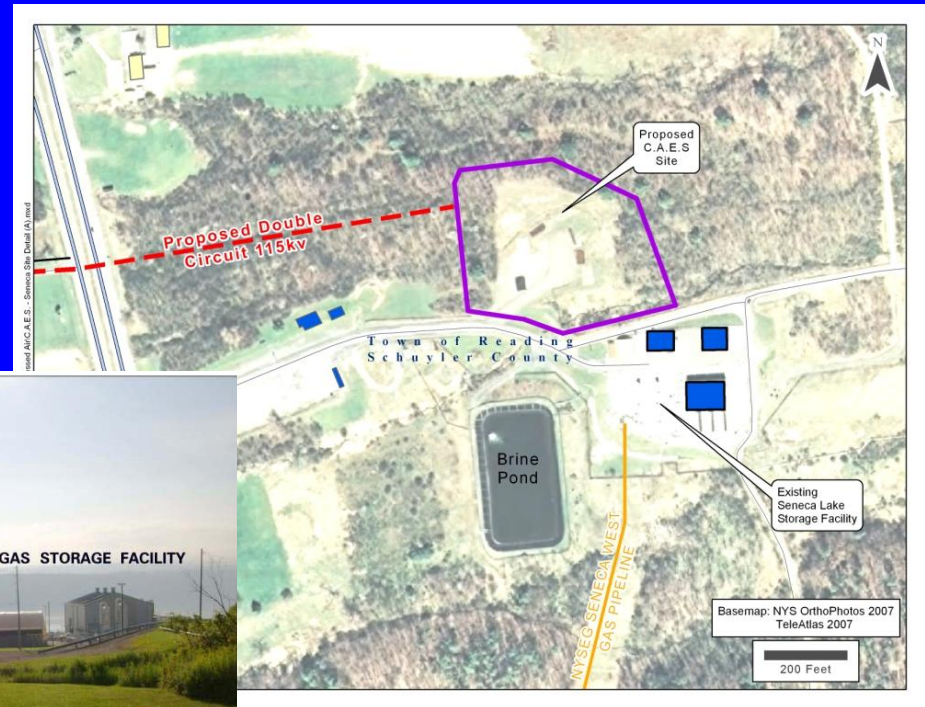
Huntorf, Germany, 290 MW



# ARRA - NYSEG:

180 MW / 10hr Compressed Air Energy Storage Facility in Watkins Glen, NY

- Layered Salt formation
- Gas Pipe Line
- Transmission Line
- Installed Wind Generation



2 CAES Projects = 450MW in Stimulus Package!

# Pumped Storage Hydro-Electric Power



Ameren: Taum Sauk, Missouri,  
440MW re-commissioned May, 2010

US – 20 GW  
EU – 32 GW  
US Proposed:  
15-30 GW



Grasslands Plan:  
3000 MW aggregated wind  
300 MW pumped hydro  
→ Green Baseload Energy

# Community Energy Storage



25 kW / 2 hrs  
15 year life time

Backup, Platform for Solar,  
Utility Dispatchable

ARRA Project puts 20 Li-Ion CES Units on Detroit Edison Grid

Widespread Adoption of EV may reduce the cost of Li-Ion Batteries  
Or else, used EV Batteries could be used for Grid Applications



## News Flash!

Consortium Initiated  
to explore Re-use of EV Batteries for Grid  
Storage Applications

DOE – OE, Storage Program

DOE – EERE, EV Program

EPA – Vehicle and Fuel Emissions Lab

ORNL – Sustainable Electricity Program

Nissan, General Motors

# 5 New Storage Technologies

Sodium Ion Battery: Aquion

Low cost, long life, aqueous sodium ion electrolyte

Flywheels: Amber Kinetics

Low cost bulk energy storage; 50kW, 50kWhr

Iron Chromium Redox: Enervault

PV Smoothing and peakshifting; 250kW, 1 MWhr

Low cost Li-Ion: Seeo

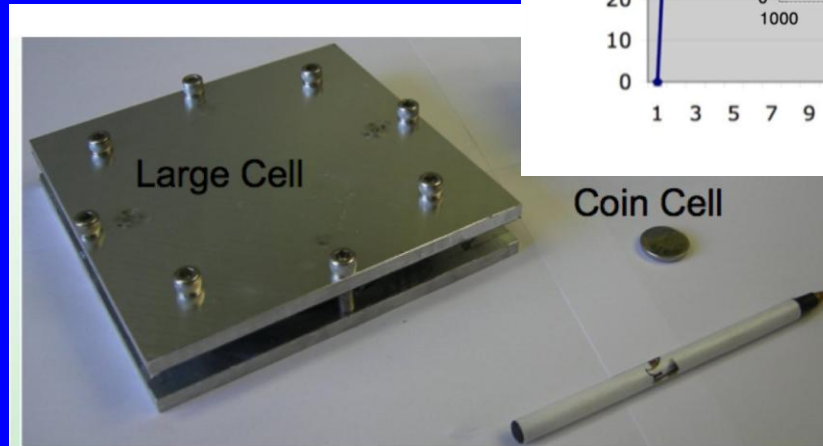
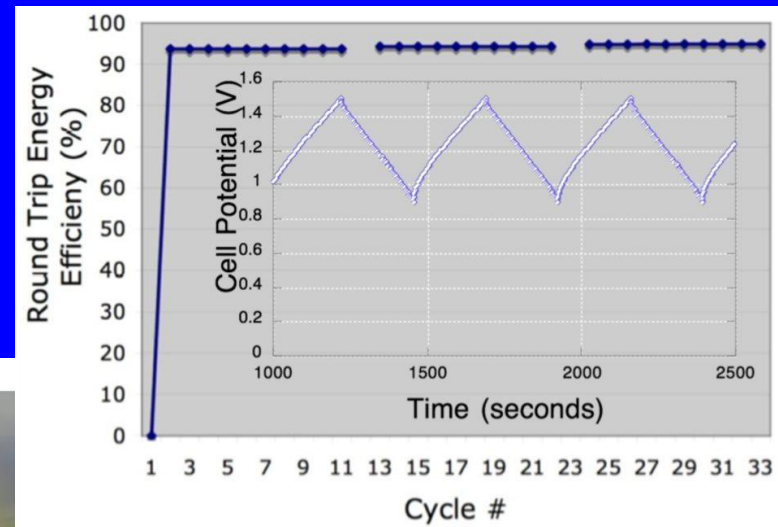
Nanostructured polymer electrolyte

Compressed Air Energy Storage

Hydraulic pump and motor; 1MW

# ARRA - Aquion Energy: Aqueous Sodium Ion Battery

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



# ARRA - Enervault: 250kW/4hr Fe-Cr Flow Battery for PV

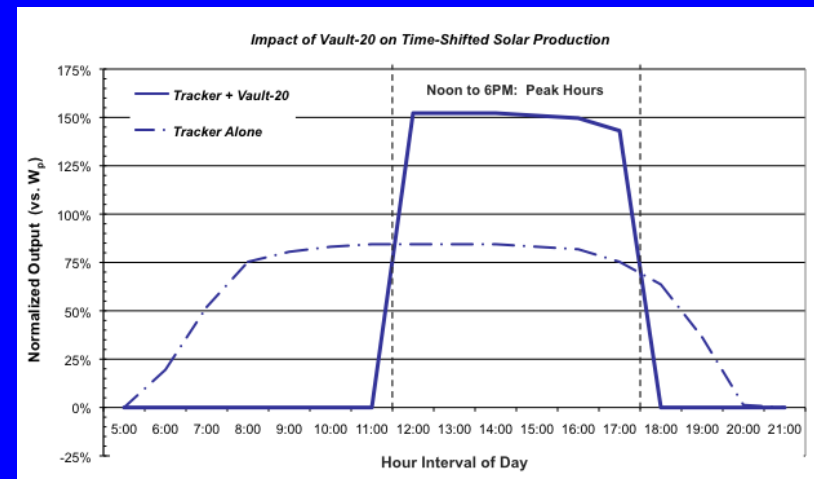
PV: 300 kW  
Storage: 250 KW  
Peak output: 450kW  
Storage Cost: +16%  
Storage Value: +84%



Tracking PV in Almond Grove



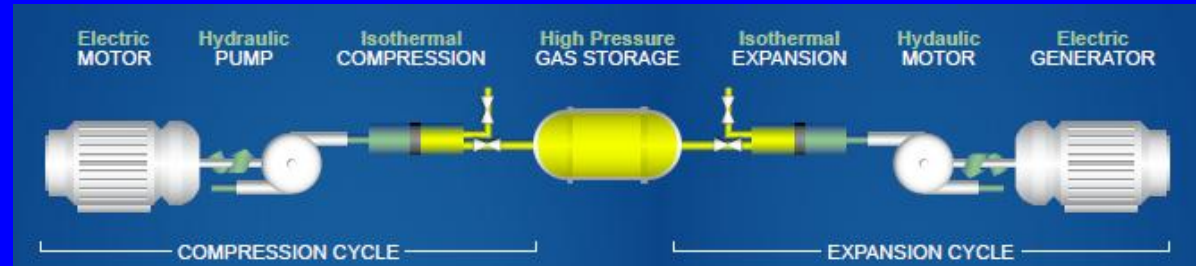
Flow Battery Prototype



Leveraging PV with Storage

# ARRA - SustainX:

Development of Isothermal Compressed Air Energy Storage Using Hydraulics



Experimental isothermal efficiency of 94.9% is achieved with the use of SustainX's technology as compared with 54% for an adiabatic technique.

**Our Goal is to make  
Energy Storage  
Ubiquitous  
on the Electric Grid!!**

# **RESOURCES:**

**[www.sandia.gov/ess](http://www.sandia.gov/ess)**

**[www.electricitystorage.org](http://www.electricitystorage.org)**

**EPRI/DOE Energy Storage Handbook**

**EESAT, Oct. 16-19, San Diego, CA**

