

# Scaling up Grid Energy Storage

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ENERGY STORAGE RESEARCH, DOE

Presented by  
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Without technological breakthroughs in efficient, large scale Energy Storage, it will be difficult to rely on intermittent renewables for much more than 20-30% of our Electricity.

*Secretary Chu, Feb. 2010*

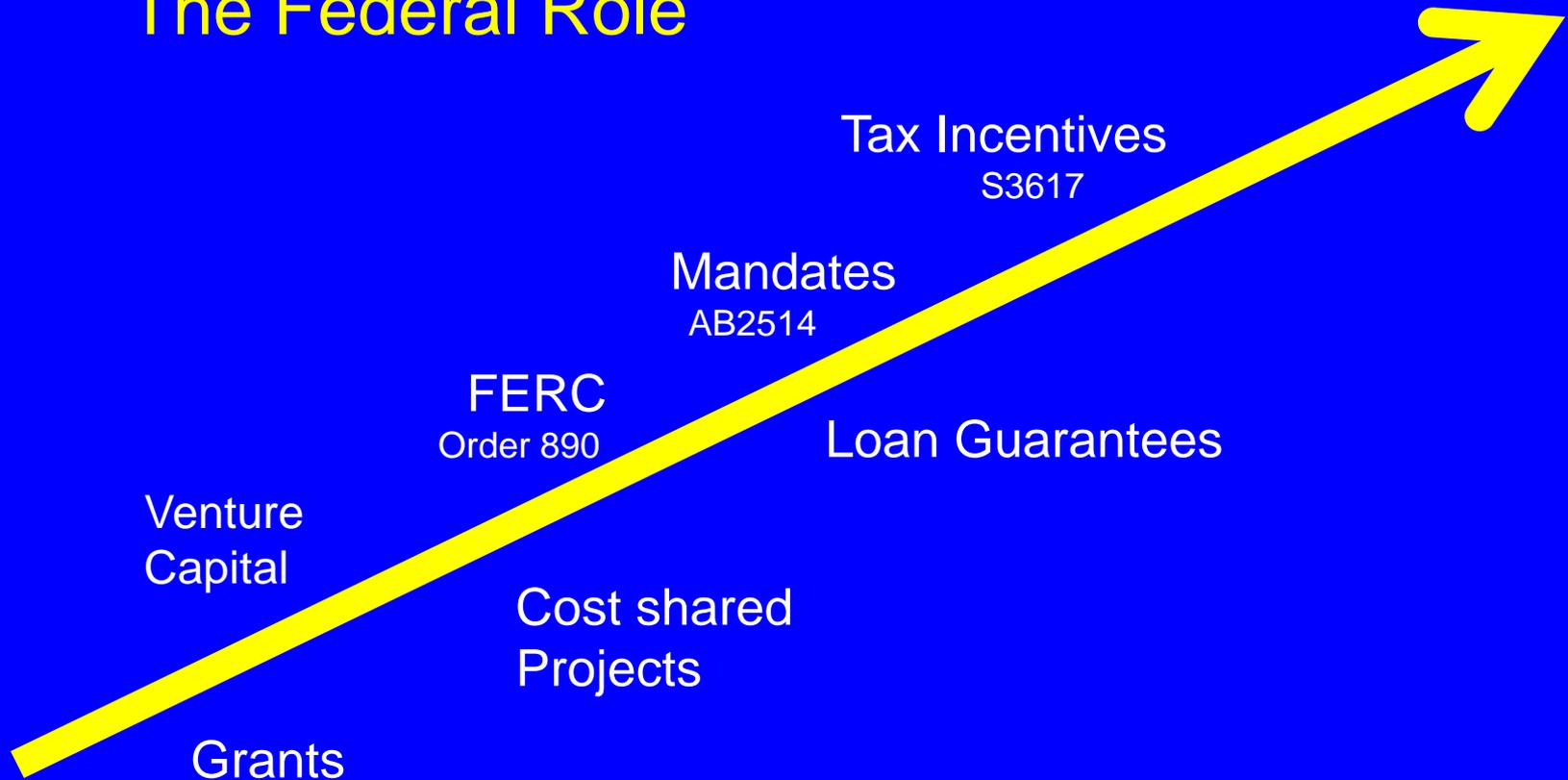
The need for regulation services can dramatically increase as the amount of variable renewable resources is increased. Local storage is among the best means to ensure we can reliably integrate renewable energy resources into the grid.

*Chairman Wellinghoff, FERC, March 2010*

Transmission and storage capacity are key issues for energy resource planning. If you like wind power, you have to love transmission and storage.

*Terry Boston , CEO, PJM, June 2010*

# The Federal Role



Research    Development    Demonstration    Niche Market    Mass Market

Energy Storage, almost unknown a decade ago, has emerged as a major focus of interest in the Utility World along with Smart Grid Technology.

The PIER program involvement with Storage started some years ago with a handshake between me and Terry Surles and a CEC/DOE Memorandum of Understanding. Since then, the CEC, along with California utilities, CAISO, and California researchers, have been leaders in the development of the storage concept and its application to the grid.

This development has culminated in the passage of AB2514 and the vigorous measures now being undertaken to let it become a tool for innovation and progress.

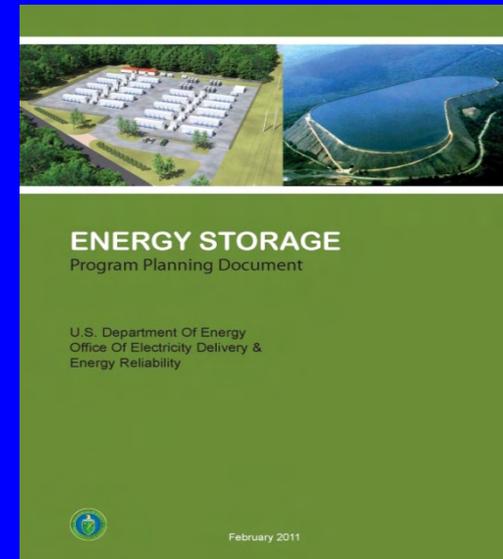
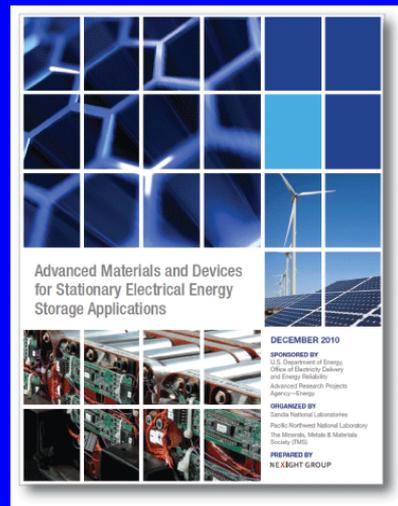
# Stakeholder Workshops and OE Program Plan



Utility Requirements  
With EERE-PV

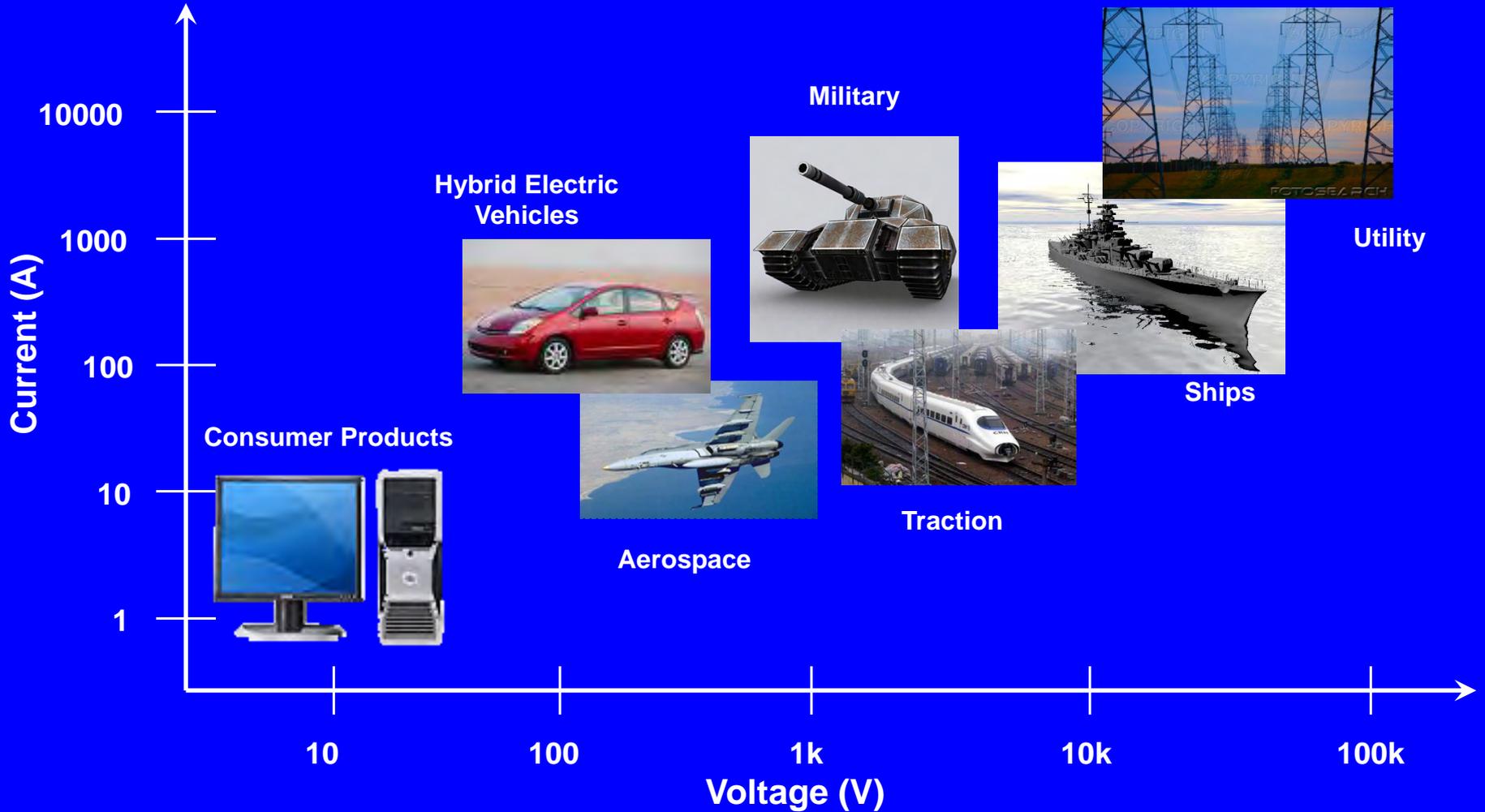
*Under the Auspices  
of the Materials Society*

Material Needs  
With ARPA-E

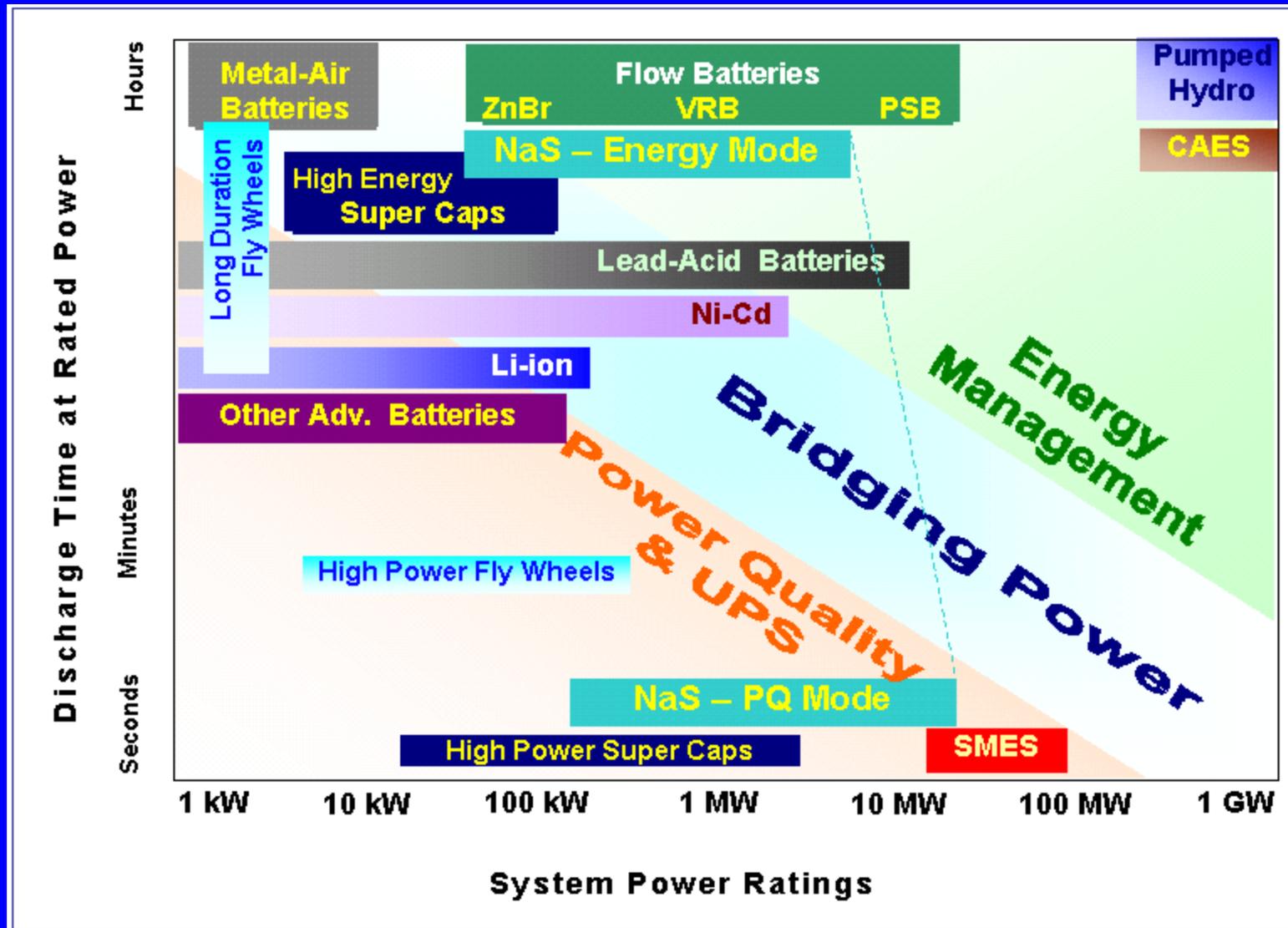


OE Energy Storage Program Plan

# 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)

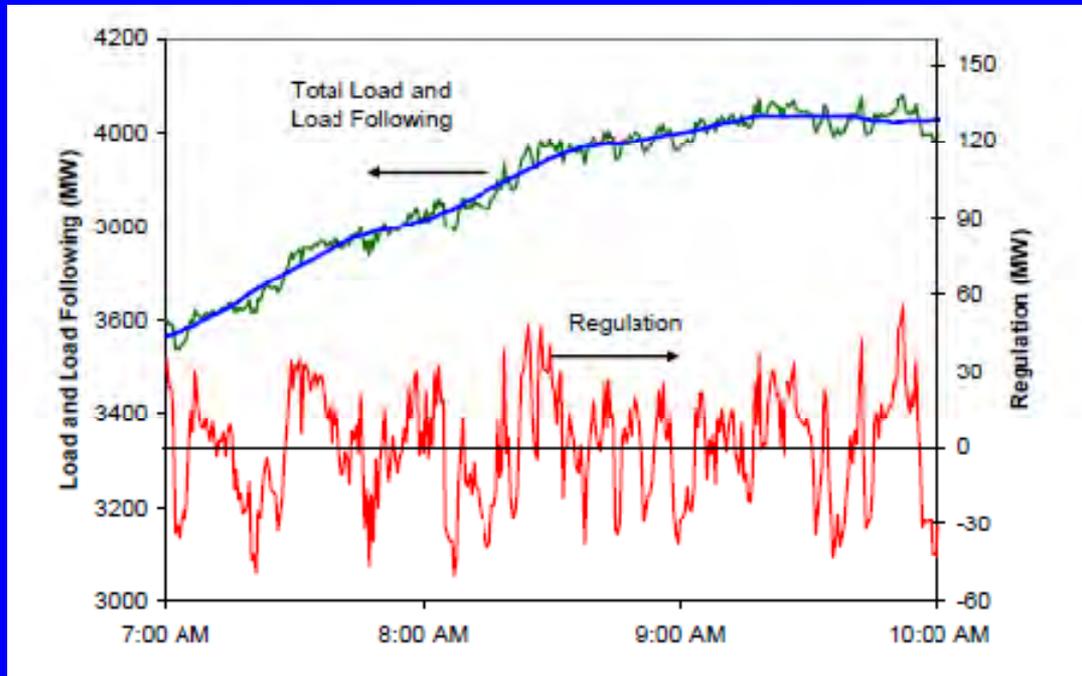
Technology Development (5 projects)

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  
14MW on Line!

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

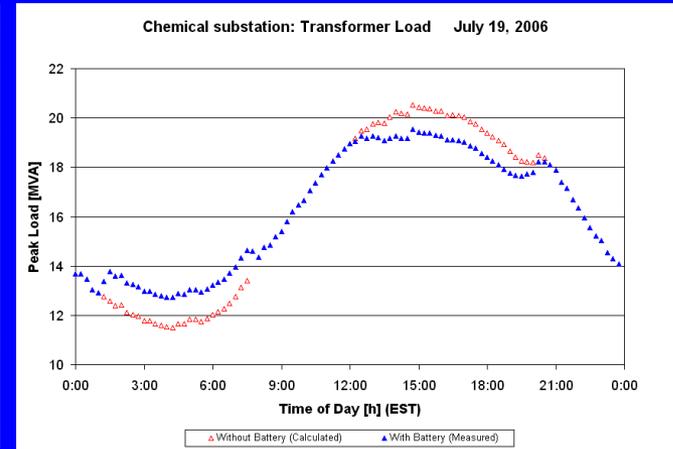


**PEAK SHAVING**

**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

ZnBr, Premium Power

Peak shaving; 5 systems @ 500kW, 2.5MWh

Lead/Carbon, EastPenn

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

Lead/Carbon, Public Service New Mexico

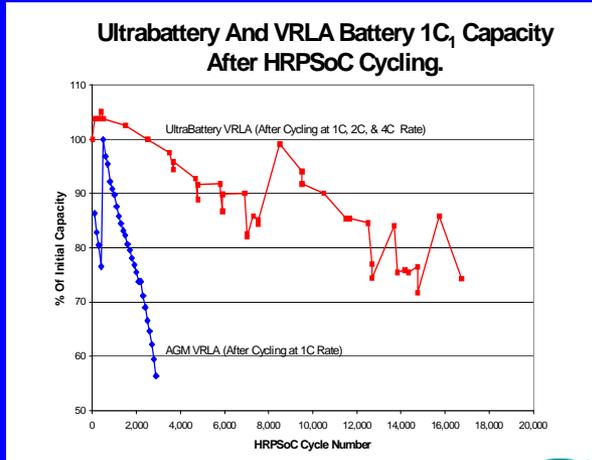
Smoothing of 500MW PV installation; 500kW, 2.5MWh

Lithium Ion, Detroit Edison, A123

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

# 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

# Community Energy Storage

25 kW / 2 hrs

15 year life time

Backup, Platform for Rooftop  
Solar, EV Charging.

Utility Dispatchable for  
Frequency Regs, Ramping, or Peaking

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

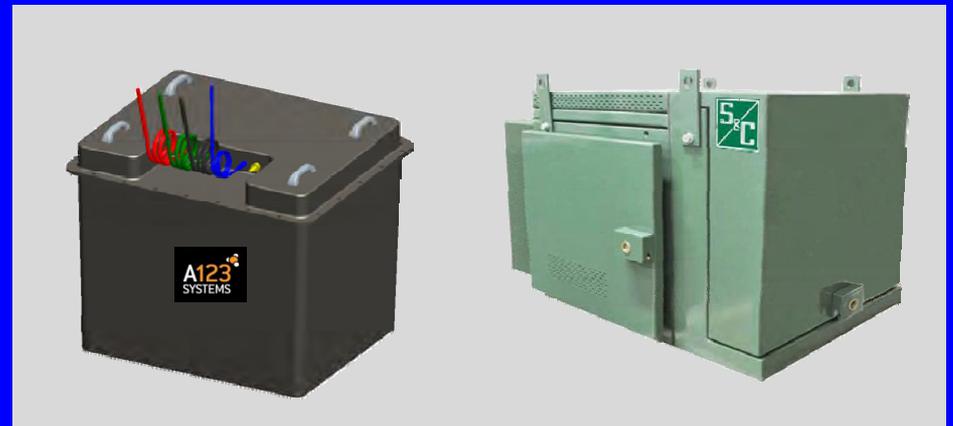


# Detroit Edison, ARRA Community Energy Storage Project

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



Monrovia County  
Community College

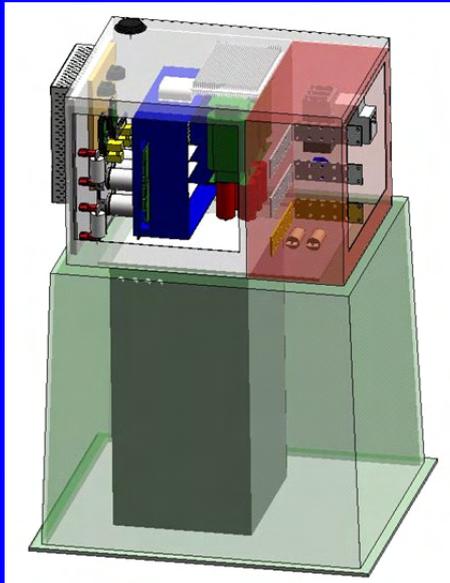


A123 Battery

S&C Inverter

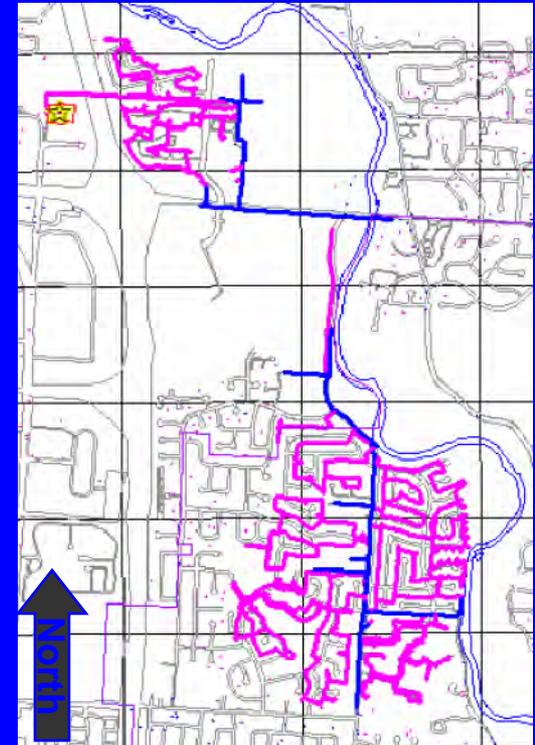
# American Electric Power Community Energy Storage ARRA Project in Columbus, OH

A fleet of 80 units,  
20 kW/1hour each  
2MW Peak shaving  
for a 6.8MW Peak



Above Ground

Entire Unit



Columbus, Ohio

# Consortium to Evaluate Re-use of EV Batteries

DOE – OE, Storage Program

DOE – EERE, EV Program

EPA – Vehicle and Fuel Emissions Lab

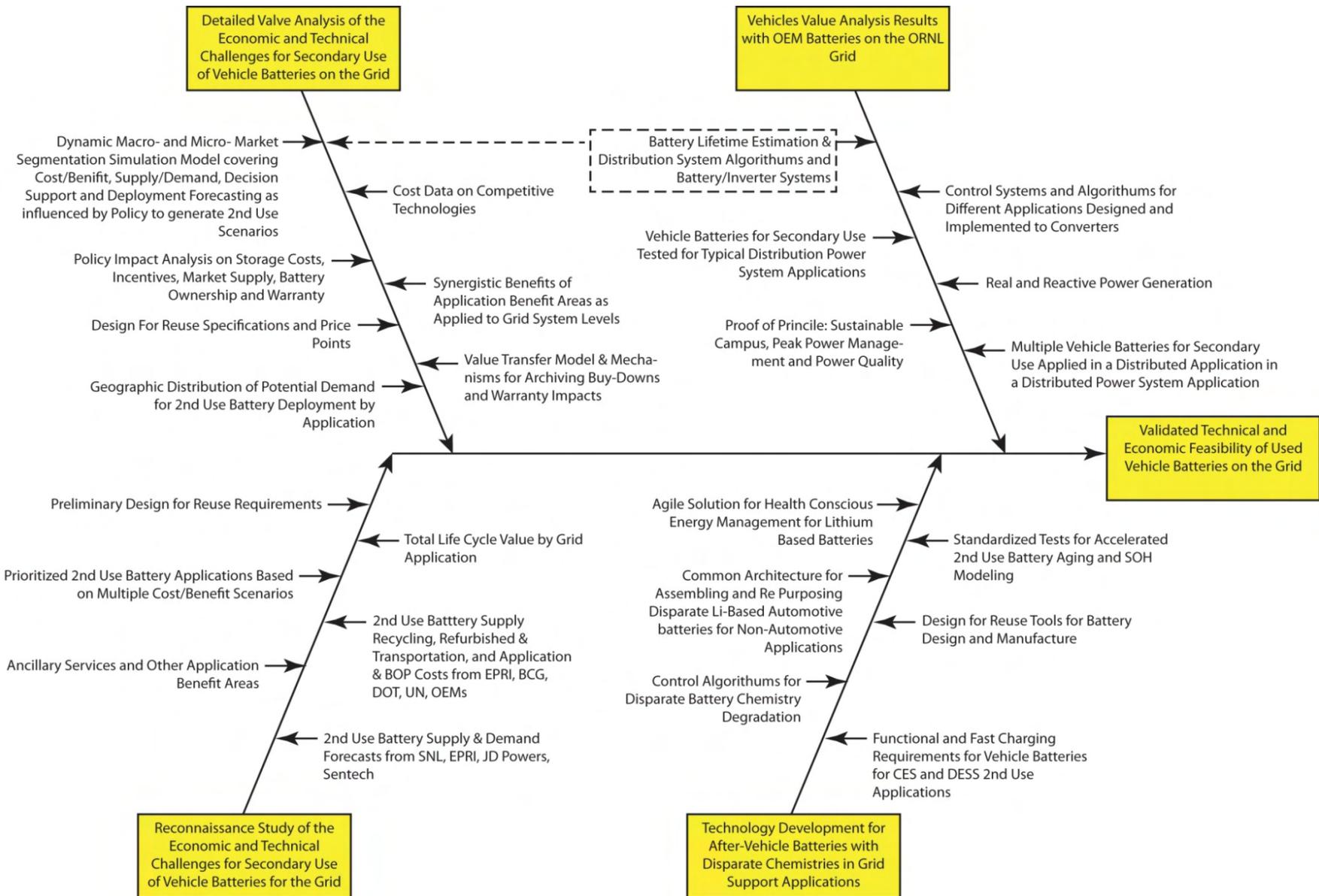
ORNL – Sustainable Electricity Program

General Motors, Nissan, BMW, Chrysler

Explore the possibility of re-using

EV batteries with 80% capacity

For Grid Storage Applications





ORNL/TM-2011/XXX

**Economic Analyses of Employing Used  
Batteries in Power Systems**

Chaitanya K. Narula  
Omer Onar  
Rocio Martinez  
George Andrews  
Month 2011

 OAK RIDGE NATIONAL LABORATORY  
MANAGED BY ORNL FOR THE DEPARTMENT OF ENERGY

## Analysis of Economic Factors shows that:

- Decreasing price of new batteries will determine cost of used batteries more than traditional supply and demand curves.
- Repackaging cost is negligible compared with transportation cost due to Li batteries being subject to DOT: 49 CFR, 173.185(d). As such, it is desirable to use on-board sensor data to select good batteries rather than transporting them to repackaging centers.

Present value of benefits for a 10-year span of energy storage in a variety of Power Systems has been calculated.

- Battery price and system cost compared with PV of benefit will enable decision process for deployment of energy storage.
- Real test data are needed to determine actual life of the energy storage system based on used batteries.

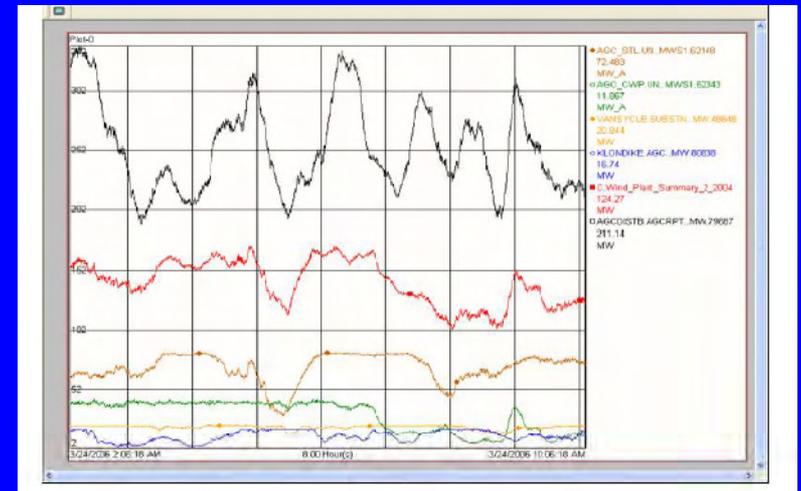
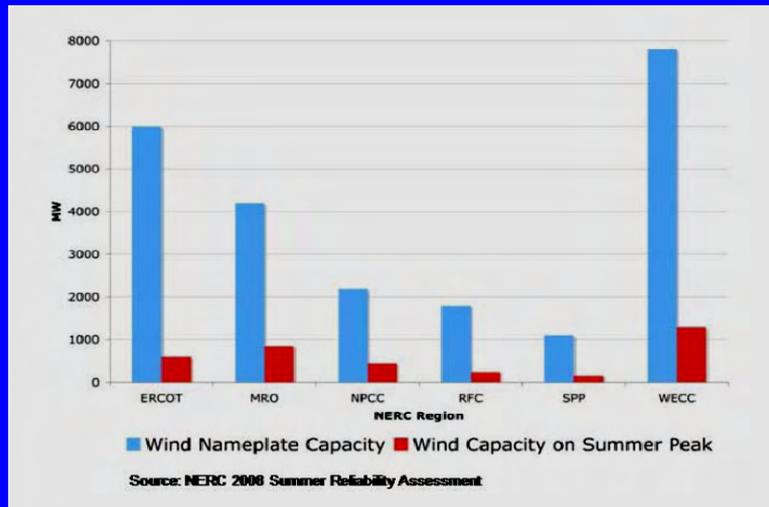
**RENEWABLES DISPATCH**

**SMOOTHING, RAMPING,**

**and PEAK SHIFTING**

*increasingly considered*

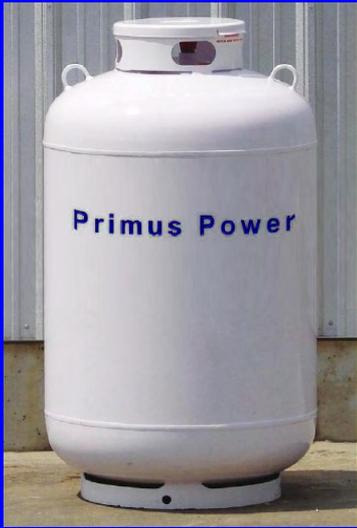
# Large Batteries for Wind Integration



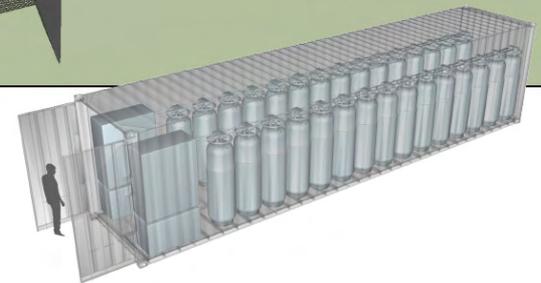
3 Large Battery + Wind Projects =  
53MW in Stimulus Package!

## 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



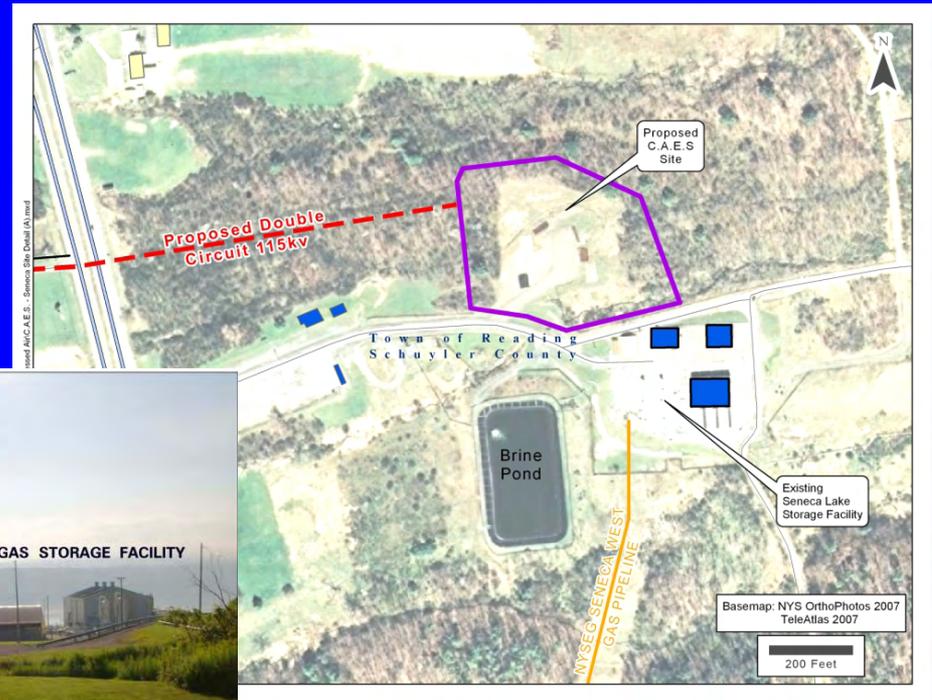
Huntorf, Germany, 290 MW



# 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



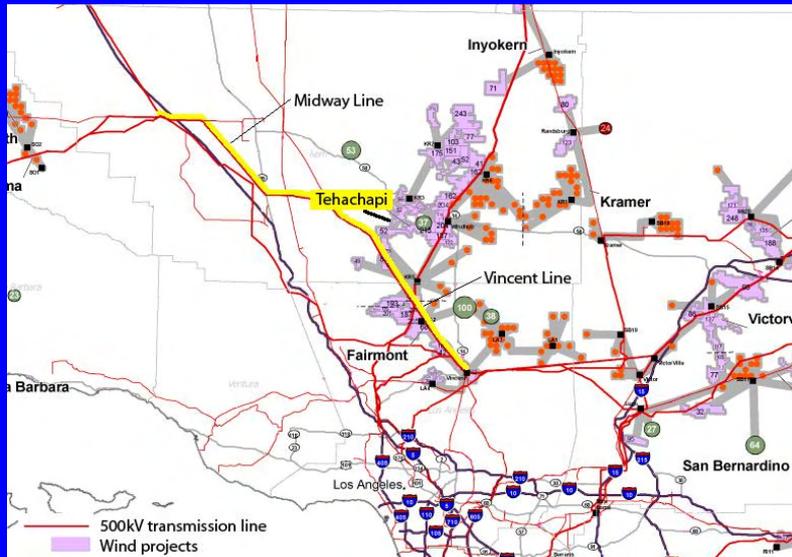
2 CAES Projects = 450MW in Stimulus Package!

# ARRA – PG&E:

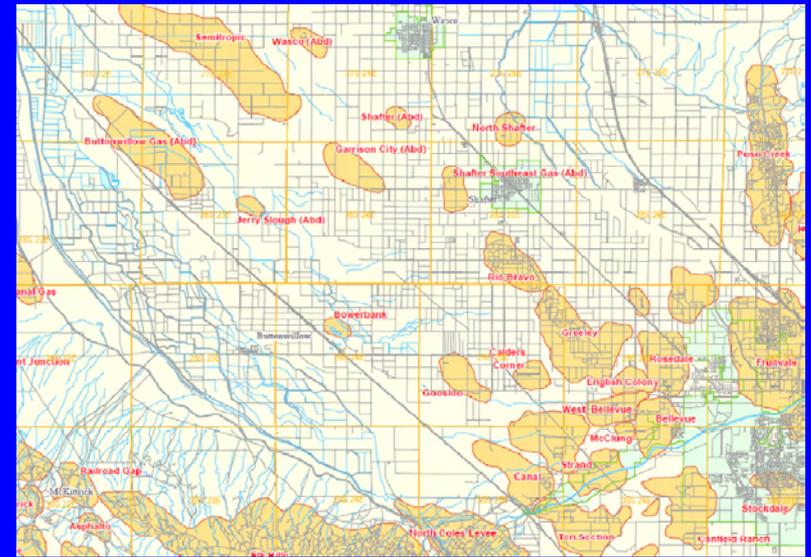
300 MW / 10hr Compressed Air Energy Storage Facility in Tehachapi, CA

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



# Electro-Thermal Energy Storage Peak Shifting

Inexpensive Off-Peak Power to make ice or chill Water. On-Peak, energy is used to displace large numbers of 3 phase inductive motor loads for compressors.

Market ready, relatively low cost, high round trip energy efficiency, long life.

Credit Suisse, NY - NYSERDA & CALMAC  
1 MW, 2 Gigawatt hours peak shift annually



Southern California Public Power Authority  
Member Utilities & Ice Energy  
53 MW for 6 hours daily during summer peak  
63 Gigawatt hours peak shift annually



Princeton University, NJ  
8 MW  
Turbine Inlet Cooling & District Cooling



# 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

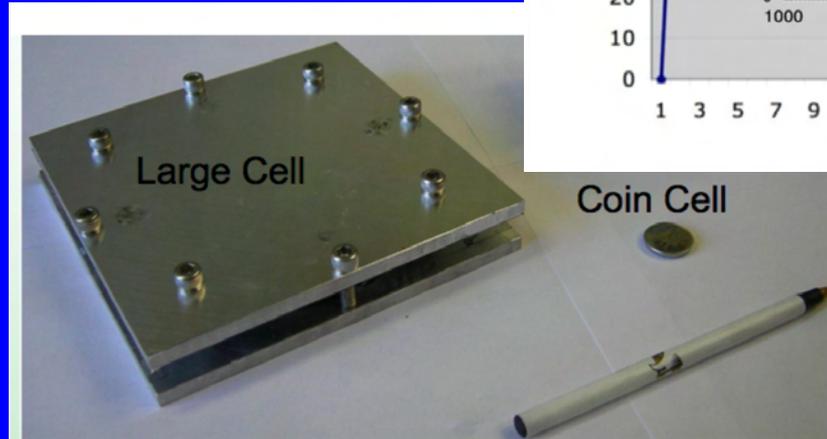
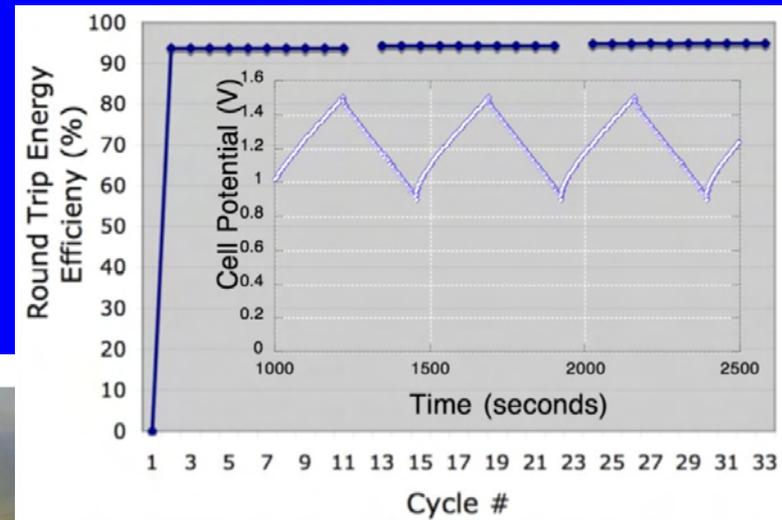
Nanostructured polymer electrolyte

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

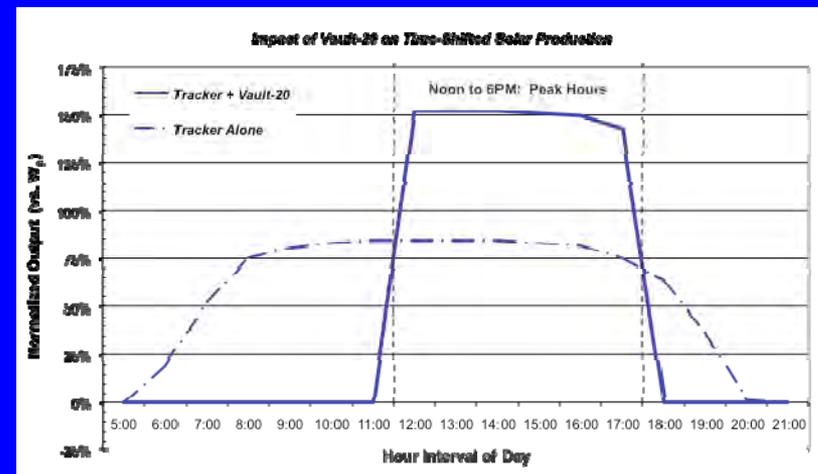
PV: 300 kW  
Storage: 250 KW  
Peak output: 450kW  
Storage Cost: +16%  
Storage Value: +84%



Tracking PV in Almond Grove



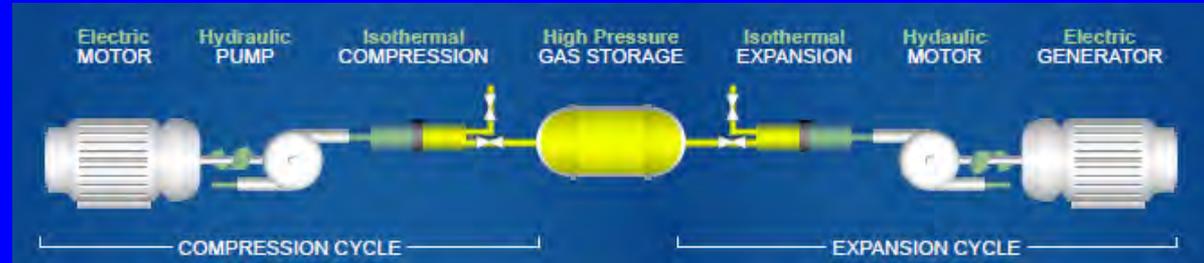
Flow Battery Prototype



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.

# **DOE Energy Storage Program**

**Aggressively Furthers**

**Market Pull and Technology Push:**

**Demonstrations and Research**

**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**

