Scaling up Grid Energy Storage

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ENERGY STORAGE RESEARCH, DOE
Presented by
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Sacramento 04 – 28 - 11

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.

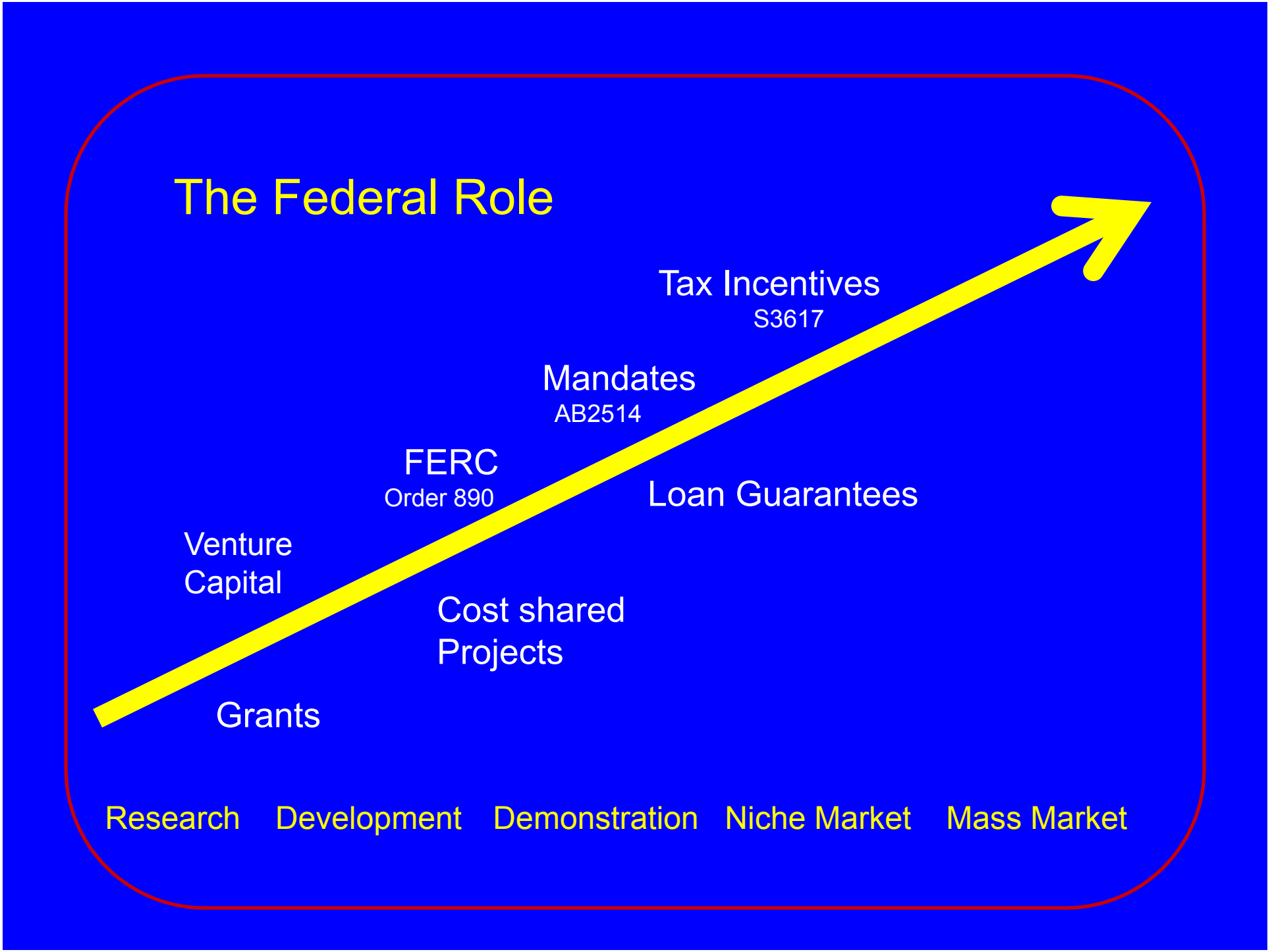
Secretary Chu, Feb. 2010

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
Tax Incentives
S3617
Mandates
AB2514
FERC
Order 890
Loan Guarantees
Venture
Capital
Cost shared
Projects
Grants
Research
Development
Demonstration
Niche Market
Mass Market

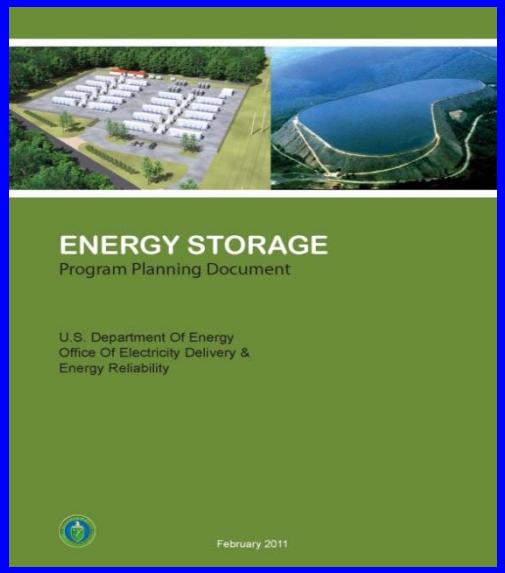
Energy Storage, almost unknown a decade ago, has emerged as a major focus of interest in the Utility World along with Smart Grid Technology.

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.

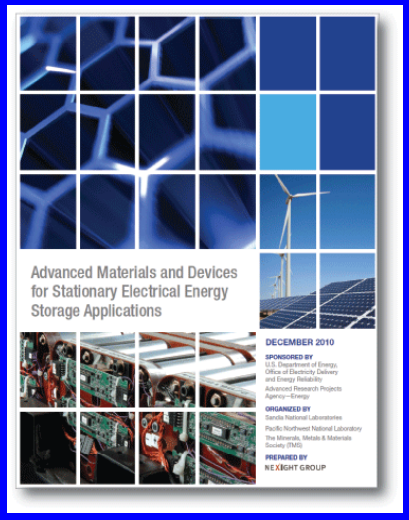
Stakeholder Workshops and OE Program Plan

Utility Requirements With EERE-PV



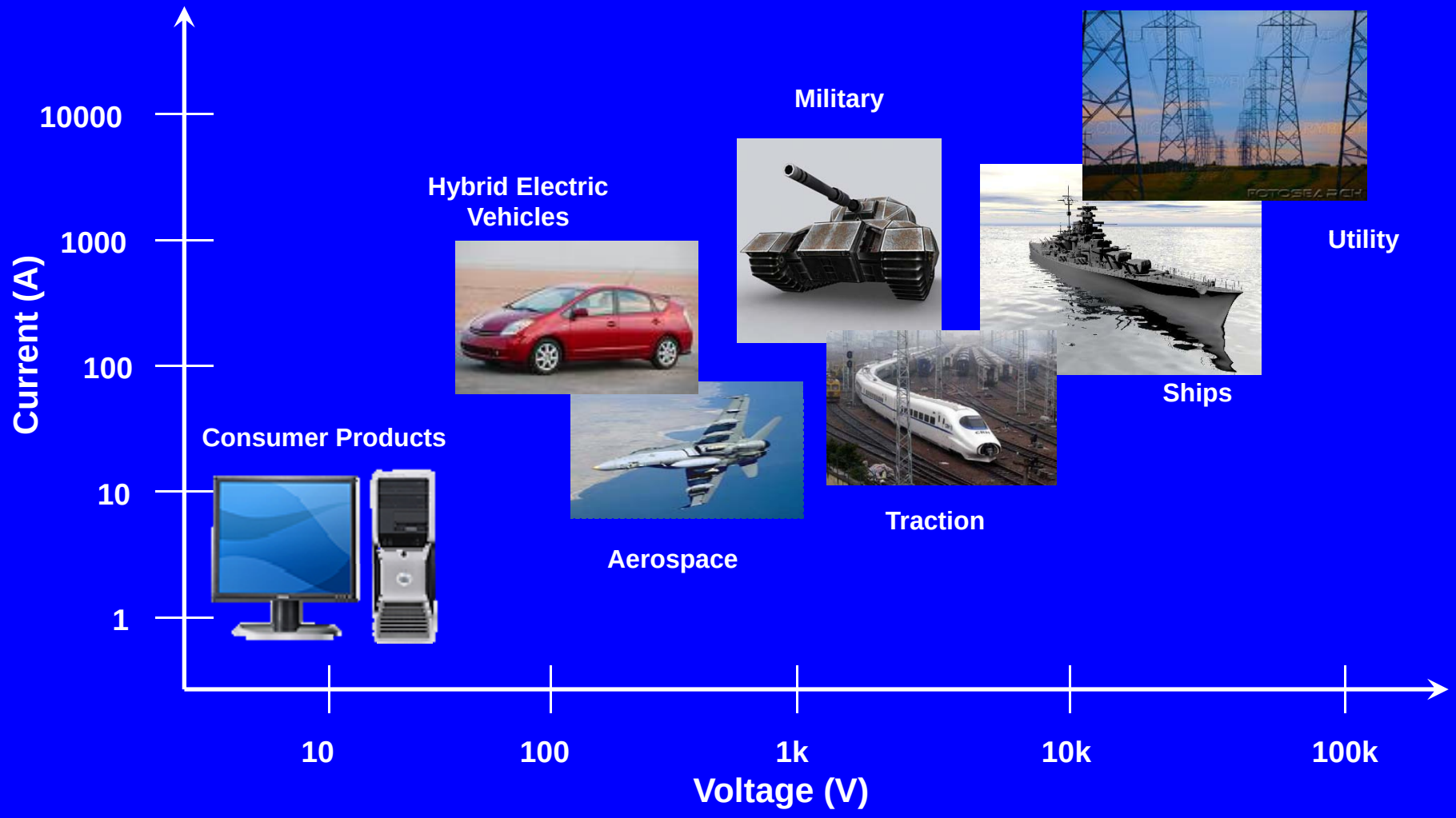
OE Energy Storage Program Plan

Under the Auspices of the Materials Society

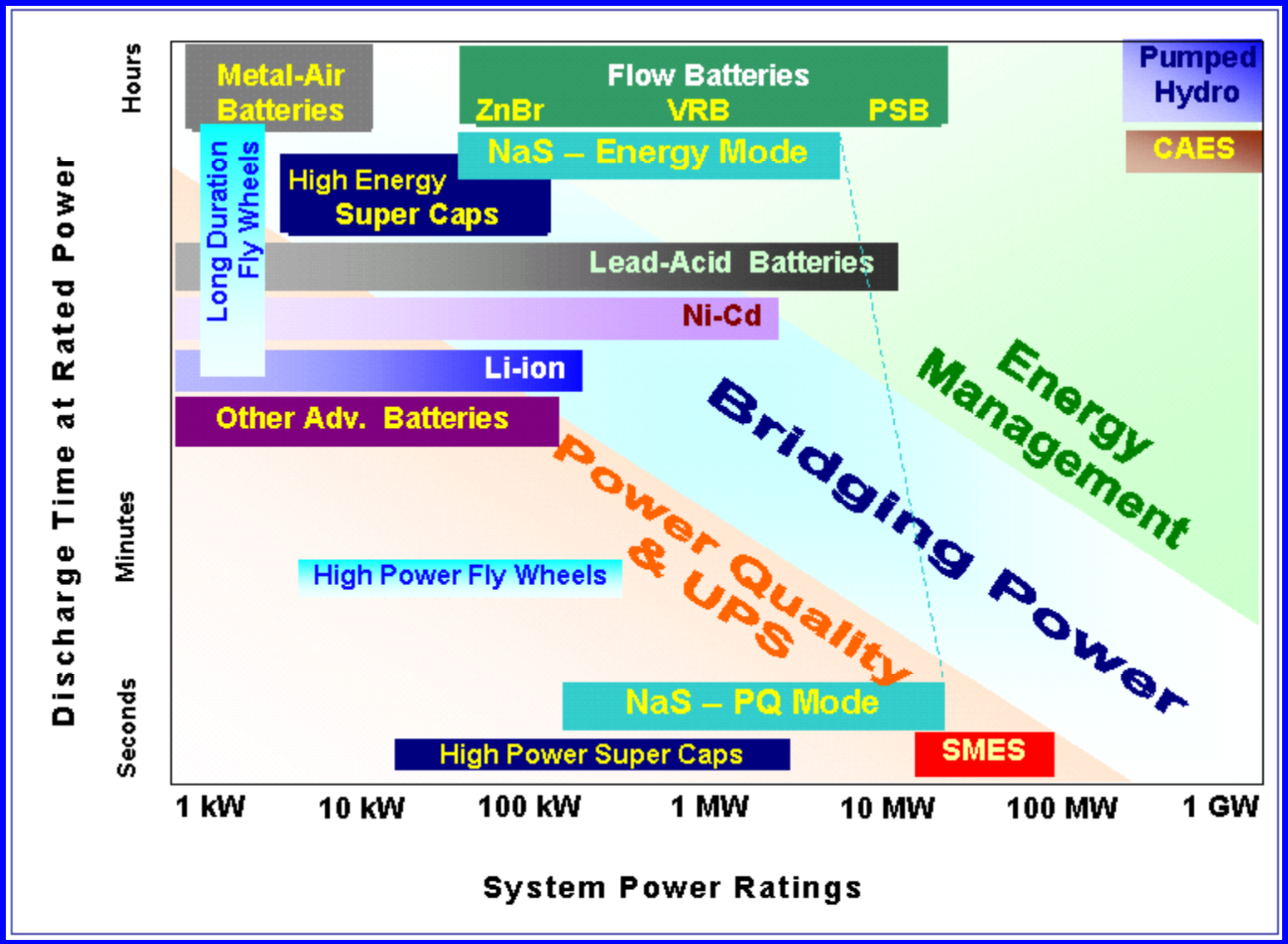


Material Needs With ARPA-E

Scales of Power



Storage Technologies and Regimes of Application



A. Nourai

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

A ten-fold Increase in Power Scale!

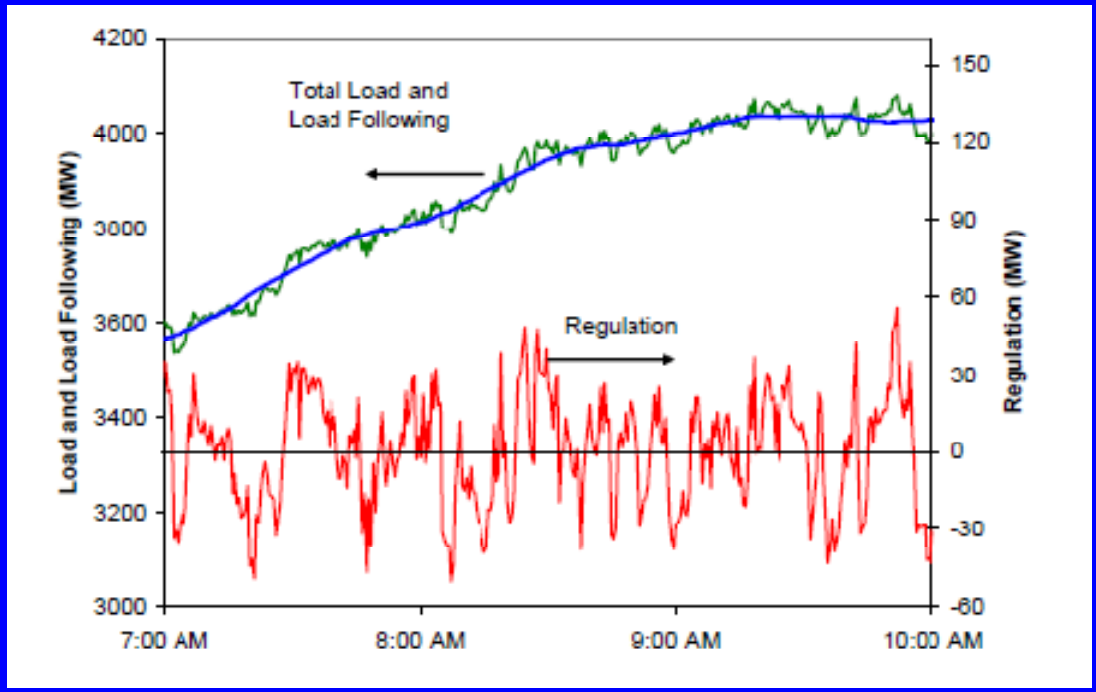
Large Battery System (3 projects,53MW)
Compressed Air (2 projects, 450MW)
Frequency Regulation (20MW)
Distributed Projects (5 projects,9MW)
Technology Development (5 projects)

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!

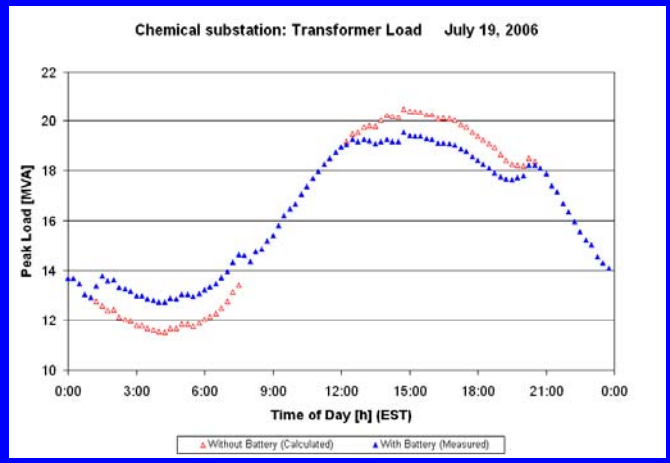
DOE Loan Guarantee – AES / A123:
20MW Lithium Ion Battery for
Frequency Regulation in NY-ISO
8MW on Line!

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

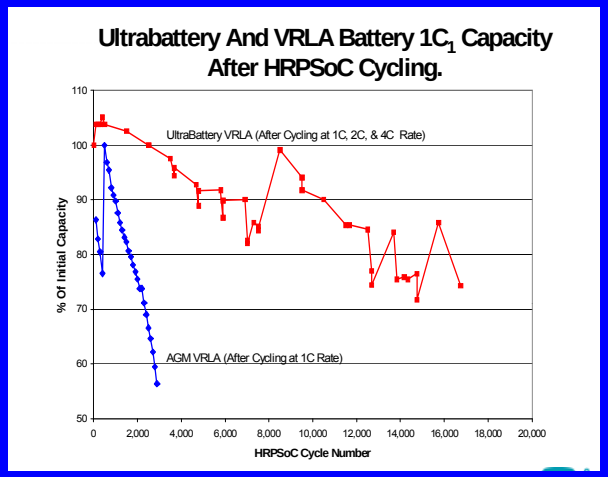
Lead/Carbon, EastPenn
Frequency regulation, Peak shifting; 3MW, 1-4MWh

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



Testing at Sandia

Battery Stacks

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

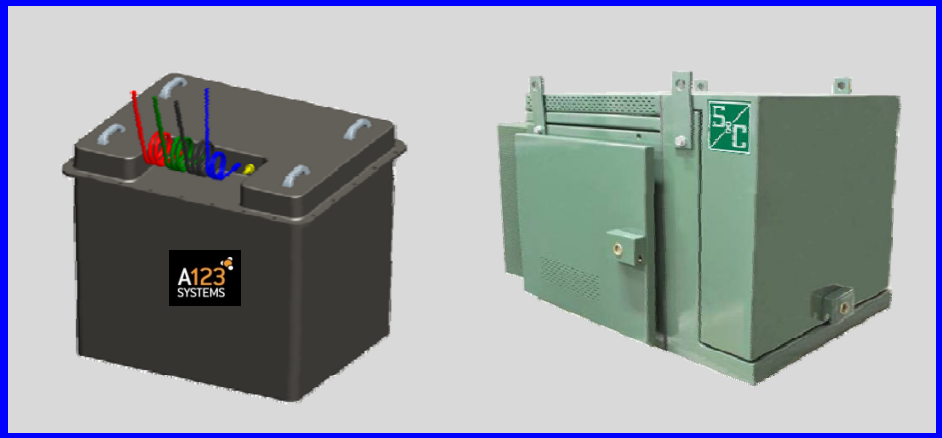
Backup, Platform for Rooftop Solar, EV Charging.
Utility Dispatchable for Frequency Regs, Ramping, or Peaking

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

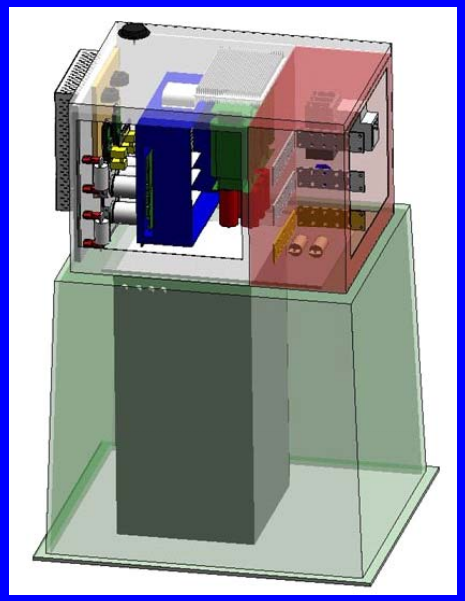


A123 Battery

S&C Inverter

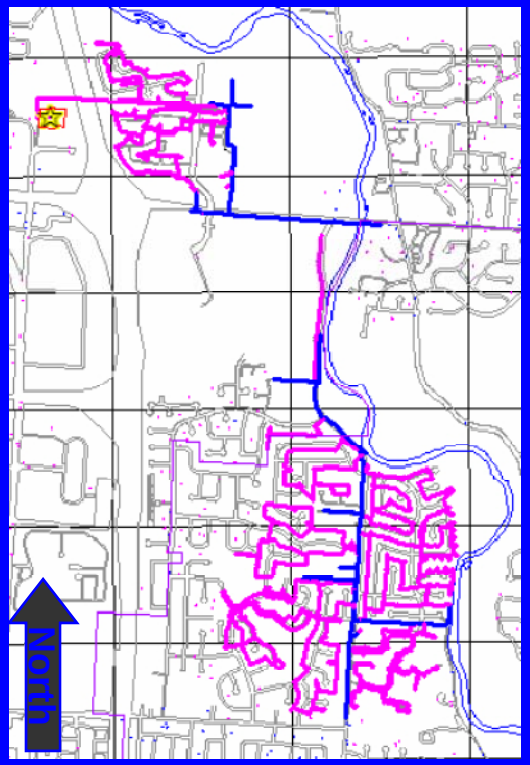
American Electric Power Community Energy Storage ARRA Project in Columbus, OH

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



Entire Unit

Above Ground

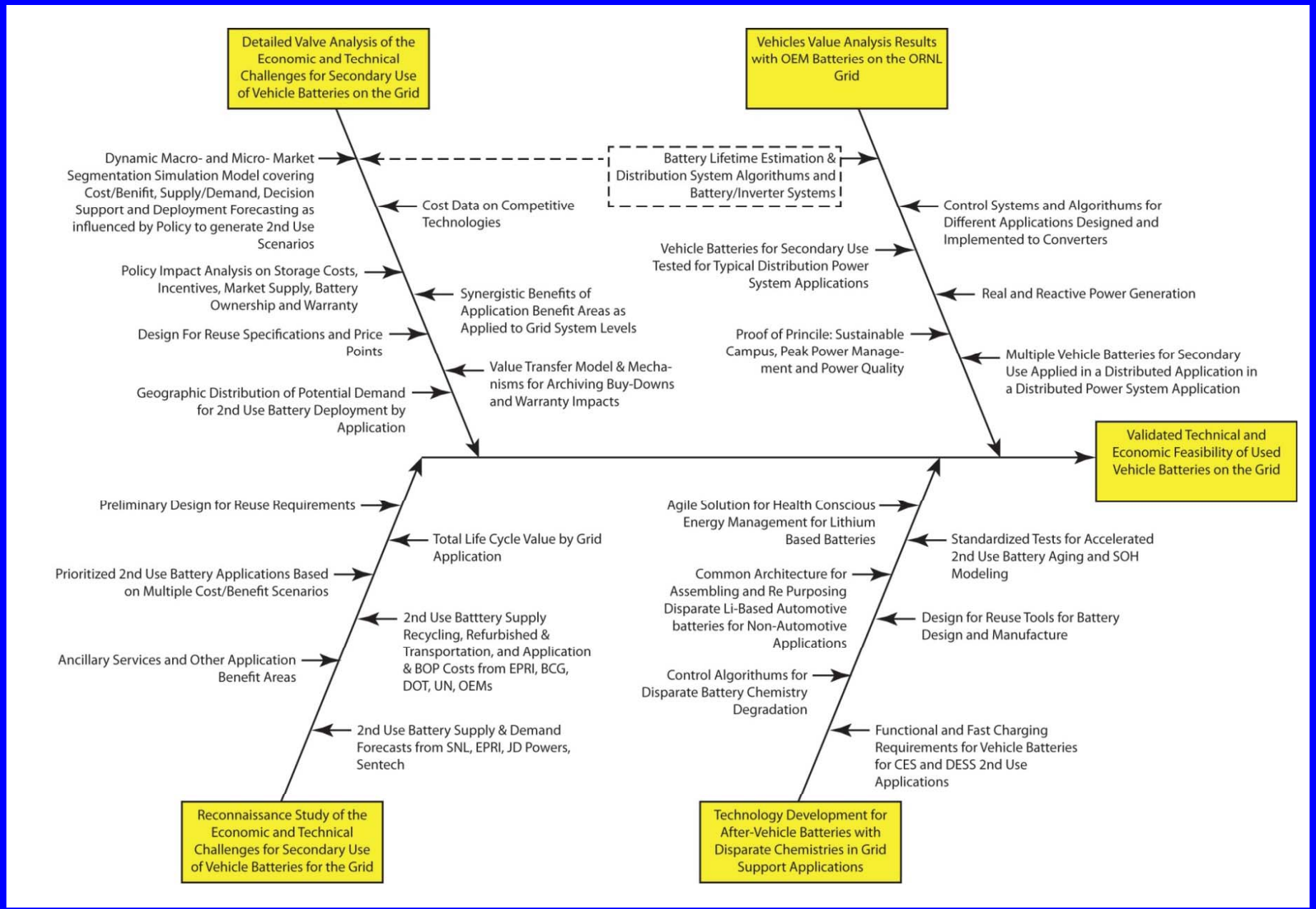


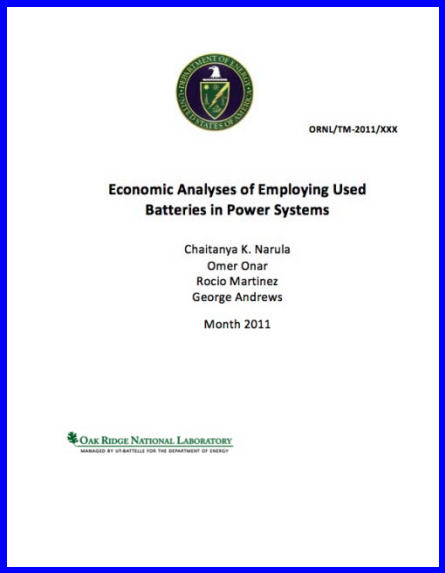
Columbus, Ohio

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


Detailed Valve Analysis of the Economic and Technical Challenges for Secondary Use of Vehicle Batteries on the Grid
Vehicles Value Analysis Results with OEM Batteries on the ORNL Grid
Dynamic Macro- and Micro- Market Segmentation Simulation Model covering Cost/Benifit, Supply/Demand, Decision Support and Deployment Forecasting as influenced by Policy to generate 2nd Use Scenarios
Battery Lifetime Estimation & Distribution System Algorithums and Battery/Inverter Systems
Cost Data on Competitive Technologies
Control Systems and Algorithums for Different Applications Designed and Implemented to Converters
Vehicle Batteries for Secondary Use Tested for Typical Distribution Power System Applications
Policy Impact Analysis on Storage Costs, Incentives, Market Supply, Battery Ownership and Warranty
Synergistic Benefits of Application Benefit Areas as Applied to Grid System Levels
Real and Reactive Power Generation
Design For Reuse Specifications and Price Points
Proof of Princile: Sustainable Campus, Peak Power Management and Power Quality
Value Transfer Model & Mechanisms for Archiving Buy-Downs and Warranty Impacts
Multiple Vehicle Batteries for Secondary Use Applied in a Distributed Application in a Distributed Power System Application
Geographic Distribution of Potential Demand for 2nd Use Battery Deployment by Application
Validated Technical and Economic Feasibility of Used Vehicle Batteries on the Grid
Preliminary Design for Reuse Requirements
Agile Solution for Health Conscious Energy Management for Lithium Based Batteries
Total Life Cycle Value by Grid Application
Standardized Tests for Accelerated 2nd Use Battery Aging and SOH Modeling
Prioritized 2nd Use Battery Applications Based on Multiple Cost/Benefit Scenarios
Common Architecture for Assembling and Re Purposing Disparate Li-Based Automotive batteries for Non-Automotive Applications
2nd Use Batttery Supply Recycling, Refurbished & Transportation, and Application & BOP Costs from EPRI, BCG, DOT, UN, OEMs
Design for Reuse Tools for Battery Design and Manufacture
Ancillary Services and Other Application Benefit Areas
Control Algorithums for Disparate Battery Chemistry Degradation
2nd Use Battery Supply & Demand Forecasts from SNL, EPRI, JD Powers, Sentech
Functional and Fast Charging Requirements for Vehicle Batteries for CES and DESS 2nd Use Applications
Reconnaissance Study of the Economic and Technical Challenges for Secondary Use of Vehicle Batteries for the Grid
Technology Development for After-Vehicle Batteries with Disparate Chemistries in Grid Support 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

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.

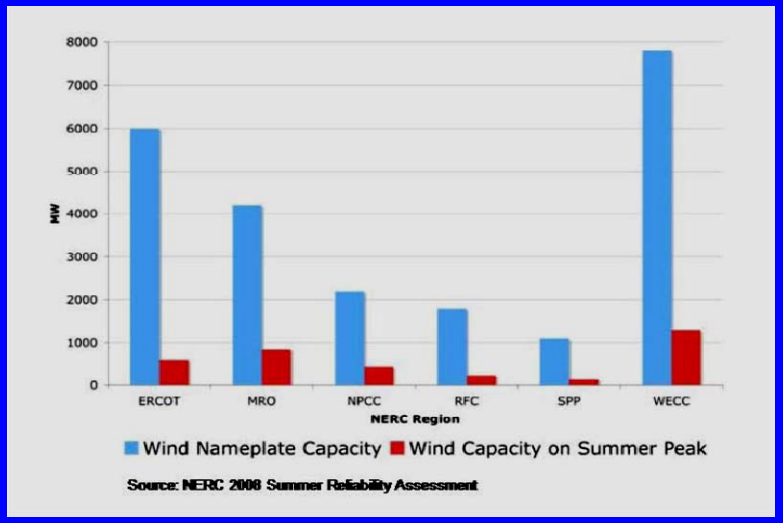
RENEWABLES DISPATCH

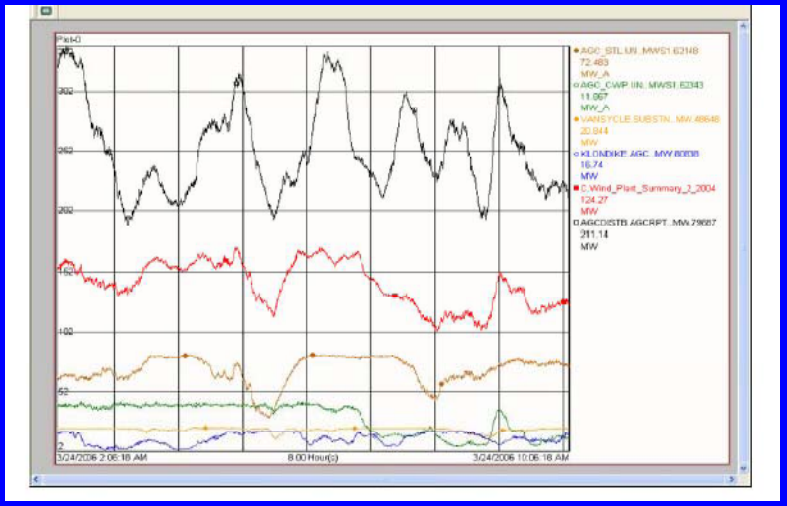
SMOOTHING, RAMPING,

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

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

Huntdorf, Germany, 290 MW

ARRA - NYSEG:

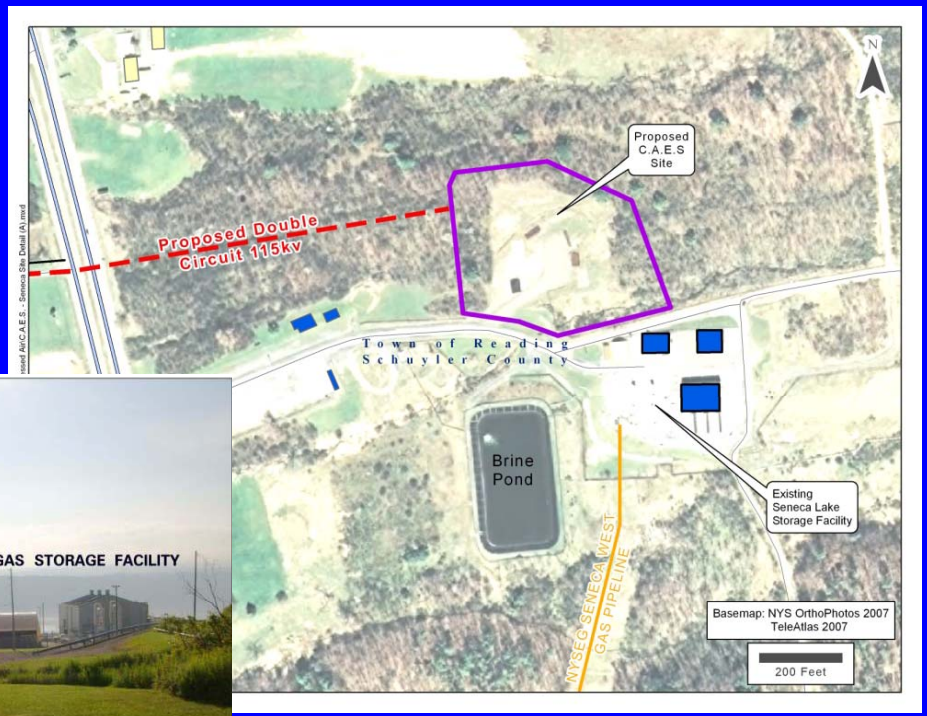
180 MW / 10hr Compressed Air Energy Storage Facility in Watkins Glen, NY

Layered Salt formation

Gas Pipe Line

Transmission Line

Installed Wind Generation



2 CAES Projects = 450MW in Stimulus Package!

ARRA – PG&E:

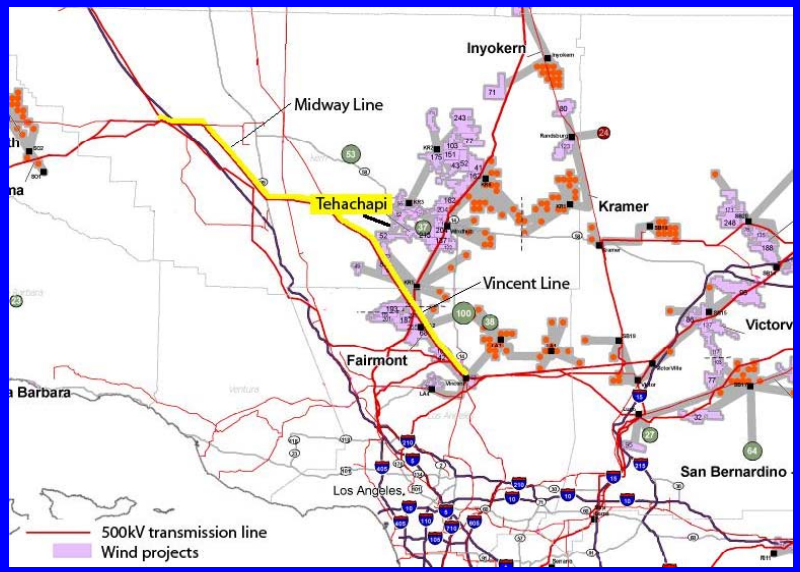
300 MW / 10hr Compressed Air Energy Storage Facility in Tehachapi, CA

Depleted Gas Wells

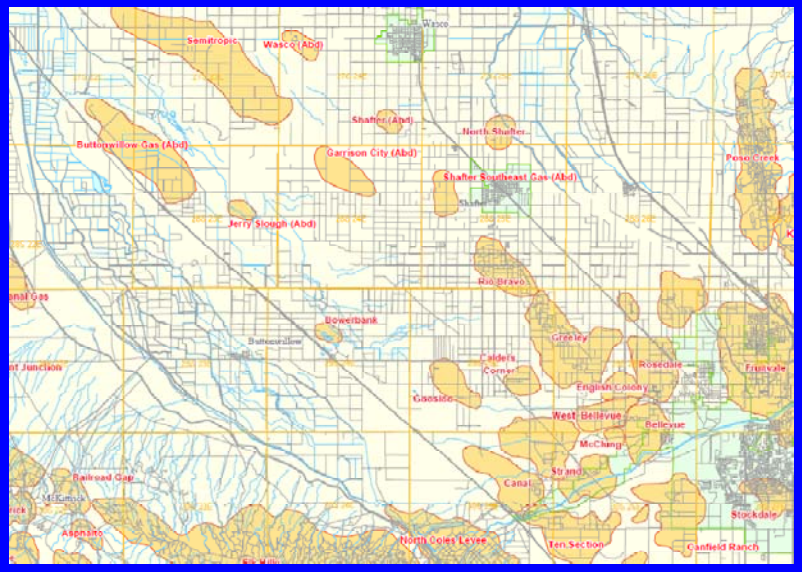
Gas Pipe Line

Existing 500kV Transmission Line

4 500 MW New Wind in 4-5 Years



Location of Wind Resources



Location of Depleted Gas Fields

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

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.

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

Credit Suisse, NY - NYSERDA & CALMAC
1 MW, 2 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

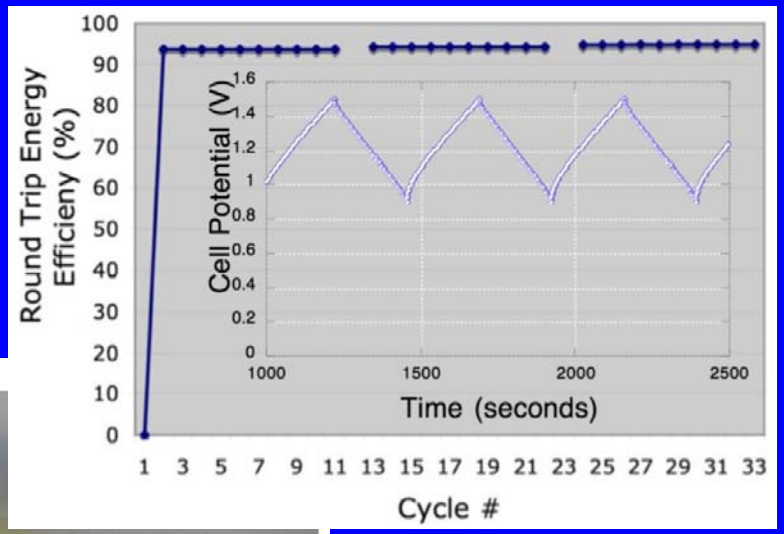
Nanostructured polymer electrolyte

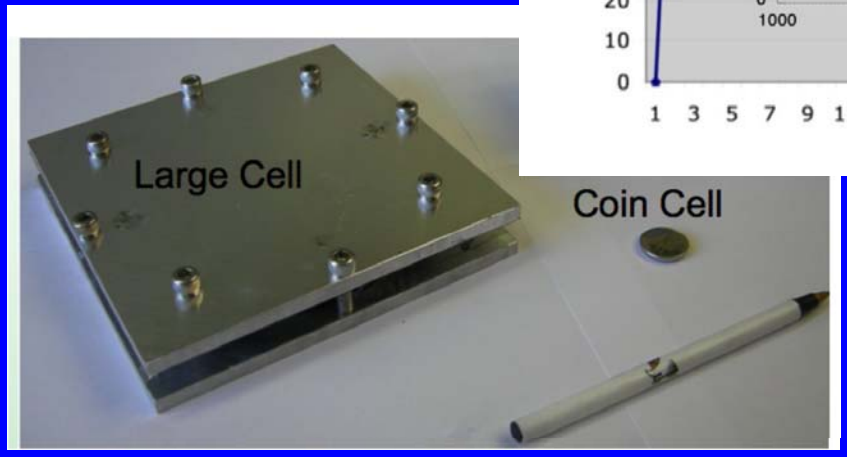
Compressed Air Energy Storage

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





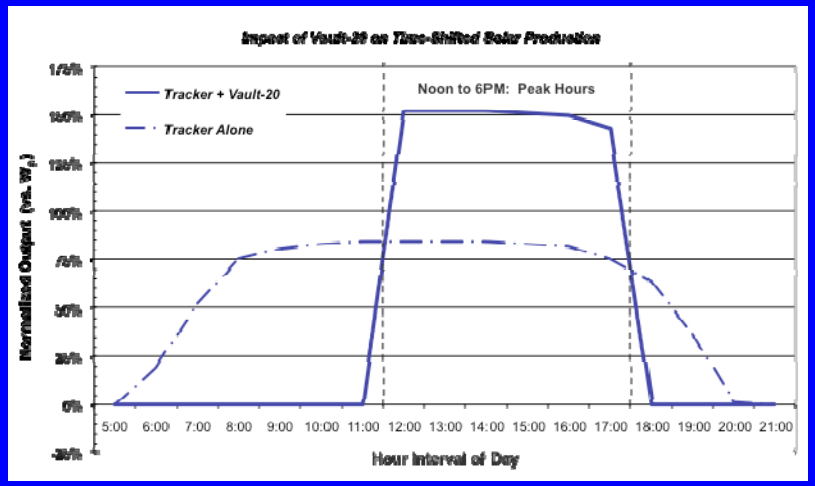
ARRA - Enervault:

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

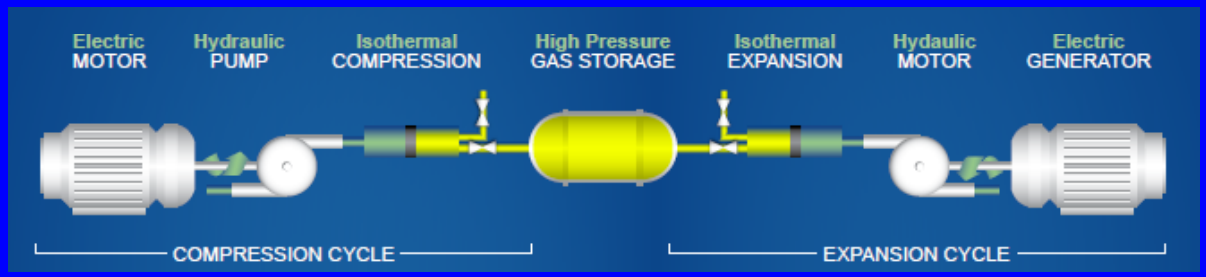
Flow Battery Prototype



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

www.electricitystorage.org

EPRI/DOE Energy Storage Handbook

EESAT, Oct. 16-19, San Diego