ENERGY STORAGE: A DISTRIBUTED RESOURCE

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Stanford 11-2-07

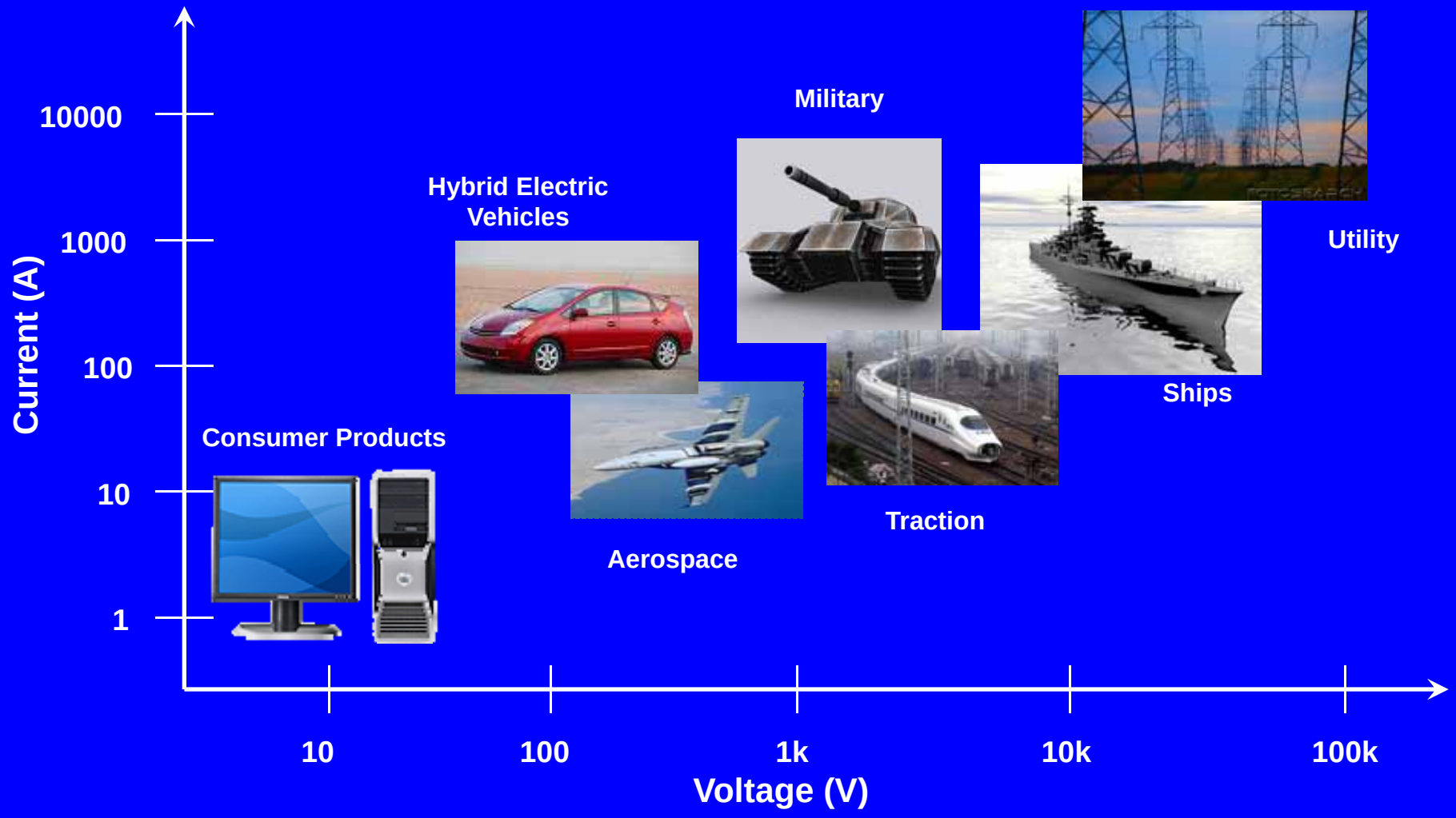
Energy Storage provides Energy

when it is needed

just as Transmission provides Energy

where it is needed

Scales of Power



DRIVERS FOR THE MODERN GRID:

DIGITIZATION OF SOCIETY:

INCREASED POWER QUALITY

ECOLOGICAL CONCERN:

DISPATCHABLE RENEWABLES

GROWTH IN ENERGY CONSUMPTION:

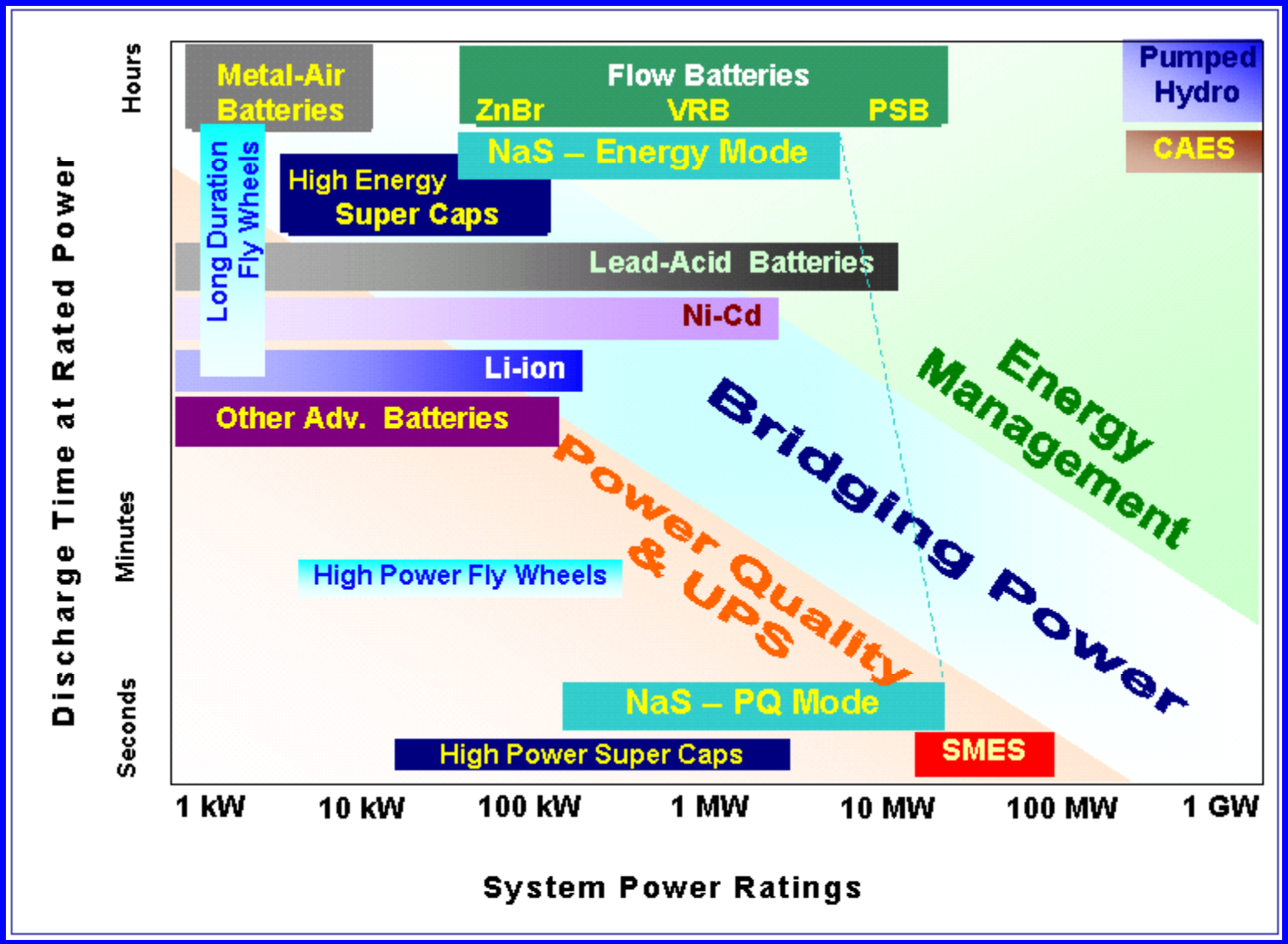
INCREASED ASSET UTILIZATION

ENERGY STORAGE OFFERS A SOLUTION!

	POWER Seconds	minutes – hours	*ENERGY* diurnal
LOAD	PQ, Digital Reliability	DER Support for Load Following	Peak Shaving to Avoid Demand Charges
GRID	Voltage Support, Transients	Dispatchability for Renewables, Micro Grids	Mitigation of Transm. Congest. Spinning Reserve

ENERGY STORAGE APPLICATIONS

Storage Technologies and Regimes of Application



A. Nourai

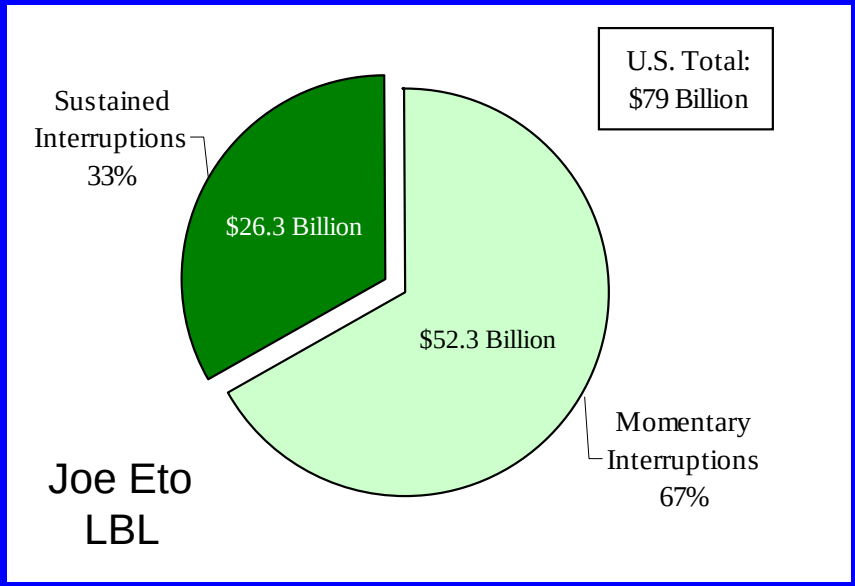
RELIABILITY AND POWER QUALITY

Has Become a Necessity for the Digital Society

Outage Costs for U.S. Industry estimated at $79 Billion Annually in a recent study by Joe Eto, LBL

Total U.S. Cost of Electricity $250 Billion Annually

Momentary Interruptions (<5min) are More Costly than Sustained Interruptions



Nine Nines of Reliability cannot be provided by Generation

Only Energy Storage can provide seamless Continuity of Power Supply

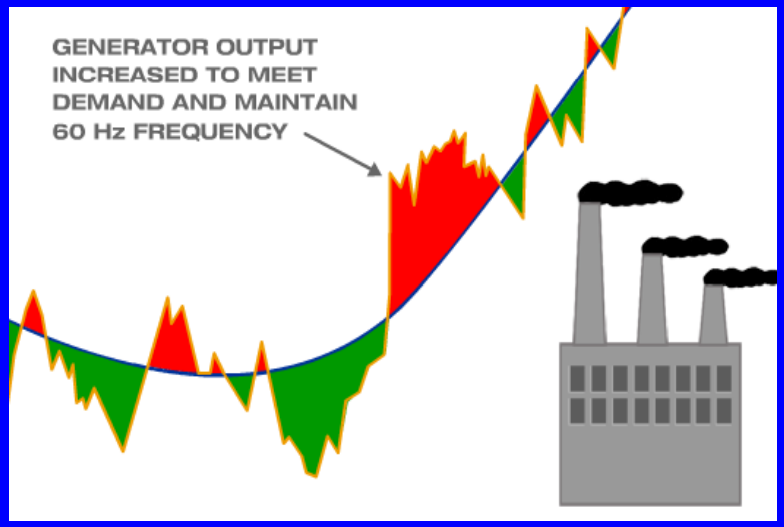
L/A Battery for Power Quality and Reliability

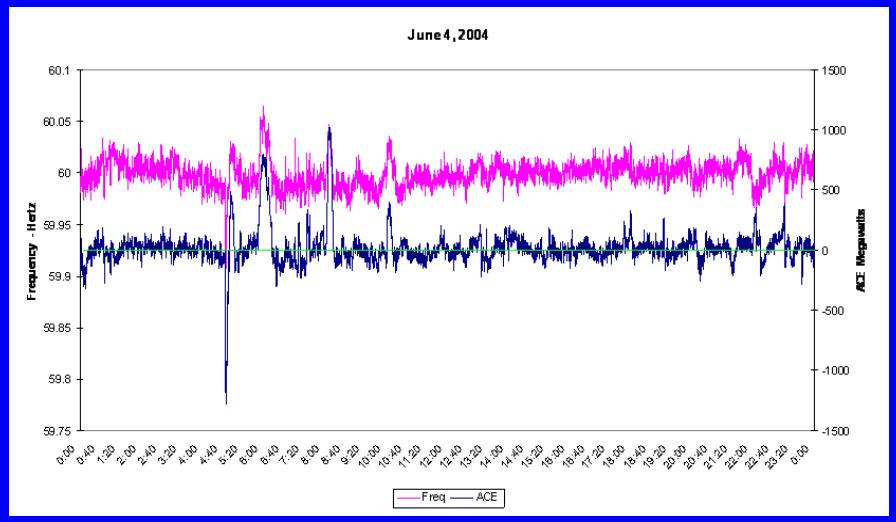
10 MW - 30 sec System at Microchip Plant

Ni-Cd Battery for Outage Support

World’s most Powerful Battery
40 MW in Fairbanks, Alaska!

Flywheels for Grid Frequency Regulation





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

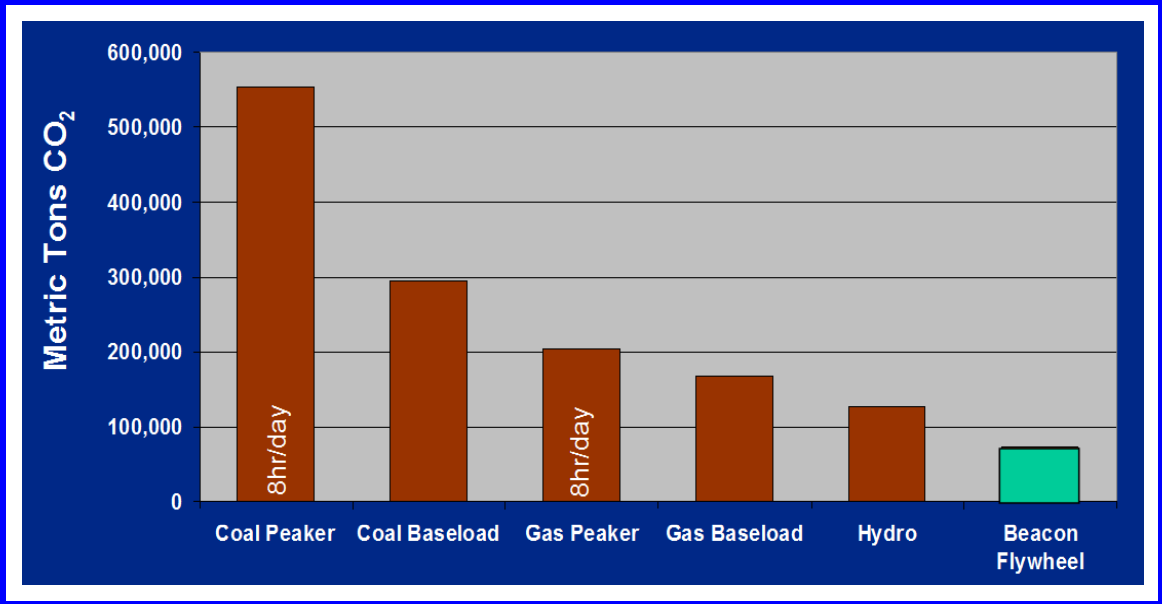
A Beacon Flywheel being assembled

Containerized 7 Flywheel System

CEC / DOE PROJECT:

Beacon Power 100 kW Flywheel System for Grid Frequency Regulation

Design for a 20MW Facility with 100kW flywheels funded by DOE



Flywheels represent an 80% reduction in CO_2 emission over present methods

In addition, Flywheels are twice as effective as Fossil Generation

100 MW of storage could eliminate 90% of Frequency Variation in California

DG LOAD FOLLOWING

MICROGRIDS

RENEWABLE DISPATCH

Aggressive Renewable Standards:

CA – 20% by 2017
NV – 20% by 2015
NY - 25% by 2013

Kyoto Protocol!!!

Such Mandates can only be reached

if Renewables are smoothed

and made dispatchable

by Energy Storage

Fossil Fuel generation produces Greenhouse Gases

In addition, Coal-fired Generation has adverse Health impacts

Ontario Medical Association estimated such Health effects at $10 Billion annually for Ontario's 3,000 MW of Coal

ULTRACAPS
FOR A 1.25 MW MICRO-GRID:

450 kW Maxwell EC-Capacitors to provide Wind Smoothing and Backup Power for the Palmdale, CA Water Treatment Plant

CEC / DOE PROJECT

GENERATION:

- 950 kW Wind Turbine (Average!)
- 2 x 225 kW Energy Bridge Ultracaps
- 800 kW + 350kW Backup Diesel
- 250 kW Natural Gas Backup Generator
- 244 kW Hydroelectric Generator

LOAD:

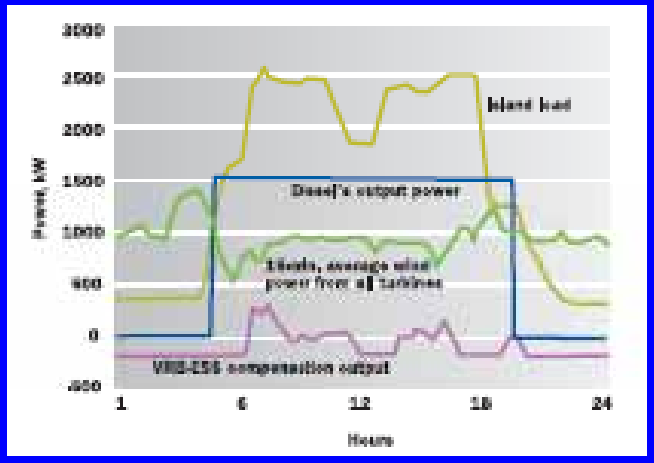
- 320 kW Critical Load
- 930 kW Non-critical Load

The Palmdale, CA Treatment Plant

Diesel / Wind / Battery Hybrid at King Island, Tasmania

1500 kW Diesel
2450 kW Wind
200 kW / 4 hrs
VRB Batteries

Batteries:
Smooth short term Wind
Firm Capacity
Load Shift to optimize Diesel

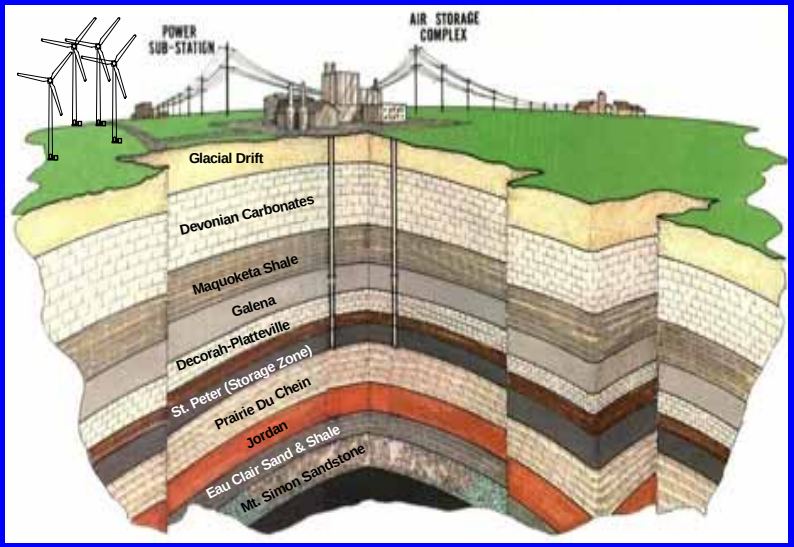


Operation Schematic

COMPRESSED AIR ENERGY STORAGE:

A DOE/ Iowa Muni Project

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



200 MW Aquifer Compressed Air Energy Storage (CAES) with 75 MW of Wind and off-peak Power planned by Iowa Associated Municipal Utilities

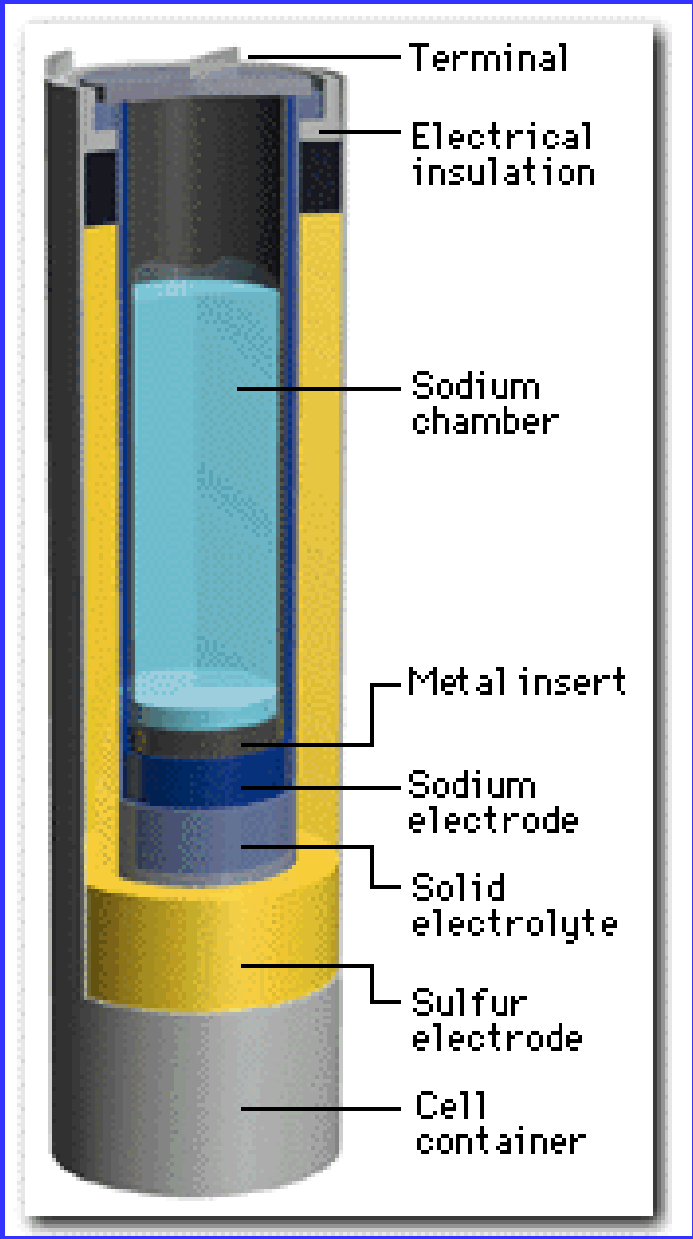
PEAK SHAVING

ENERGY MANAGEMENT

UPGRADE DEFERRAL

SODIUM-SULFUR (NAS) BATTERY

6 MW / 8hrs NGK Sodium-Sulfur Batteries for Load Management and Backup at a Japanese Resort Town



Schematic Diagram of NaS Cell

1MW NaS Battery to Store Off Peak Power

NYSERDA / DOE PROJECT:
For 1,800HP Natural Gas Compressor in a Long Island NG Refueling Station for 220 Busses

Relieves LIPA Peak Load, Eliminates Night Shift at Plant

Partnership with NYPA

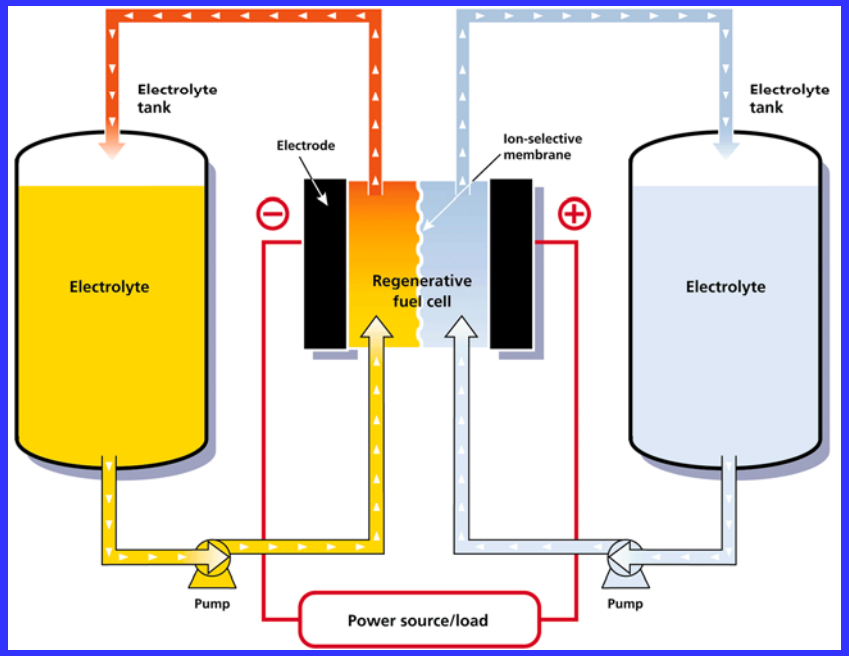
Costshares from NY ISO, TVA, EPRI, Southern, First Energy, ComEd, PSE&G, APPA, LIPA, Hydro Quebec, San Diego G&E

Three 600-HP compressors + 1 MW NaS battery

FLOW BATTERIES:

Power and Energy are separated.
Power Depends on the Conversion Cell
Energy Depends on the Stored Electrolyte

- Vanadium Redox
- Zinc-Bromine



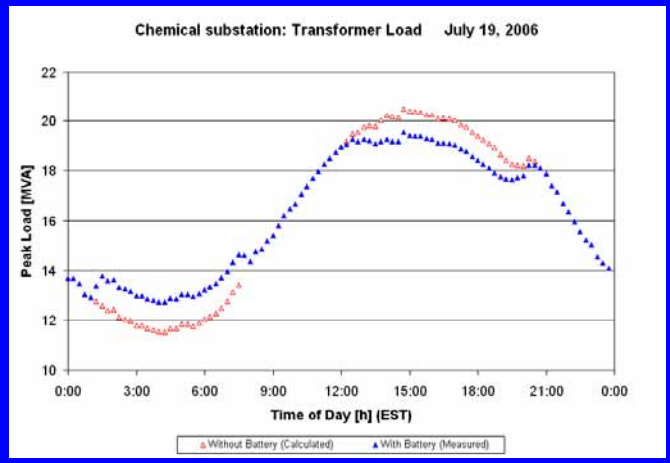
Vanadium Redox Battery at Rattlesnake #22

- Castle Rock, Utah, at the End of a 209 Mile 125kV Feeder
- Feeder too small for Peak Loads
- Complaints about Outages, PQ
- Upgrade costly and 3 year delay
- DG not acceptable for Pollution Reasons

CASTLE ROCK, UTAH

VRB TANK INSTALLATION

500kW / 2MWh
Vanadium Redox Battery
By VRB Power Systems
Expandable to 1MW
Provides Peak Power
Without Distrib. Upgrade



Charleston, WV Appalachian Power Substation

1.2 MW / 6hr NaS Battery for Substation Support:

- First Commercial Application in US.
- Provides Backup during Peak Load
- Defers Upgrade by 5 to 6 Years
- Reduces Transformer Heat up
- Potential Arbitrage Benefits 10K/month

AEP / DOE PROJECT

Generic Design funded by DOE

S&C Power Conditioning System developed with DOE Funding (R&D 100)

Commissioned June 26, 2006

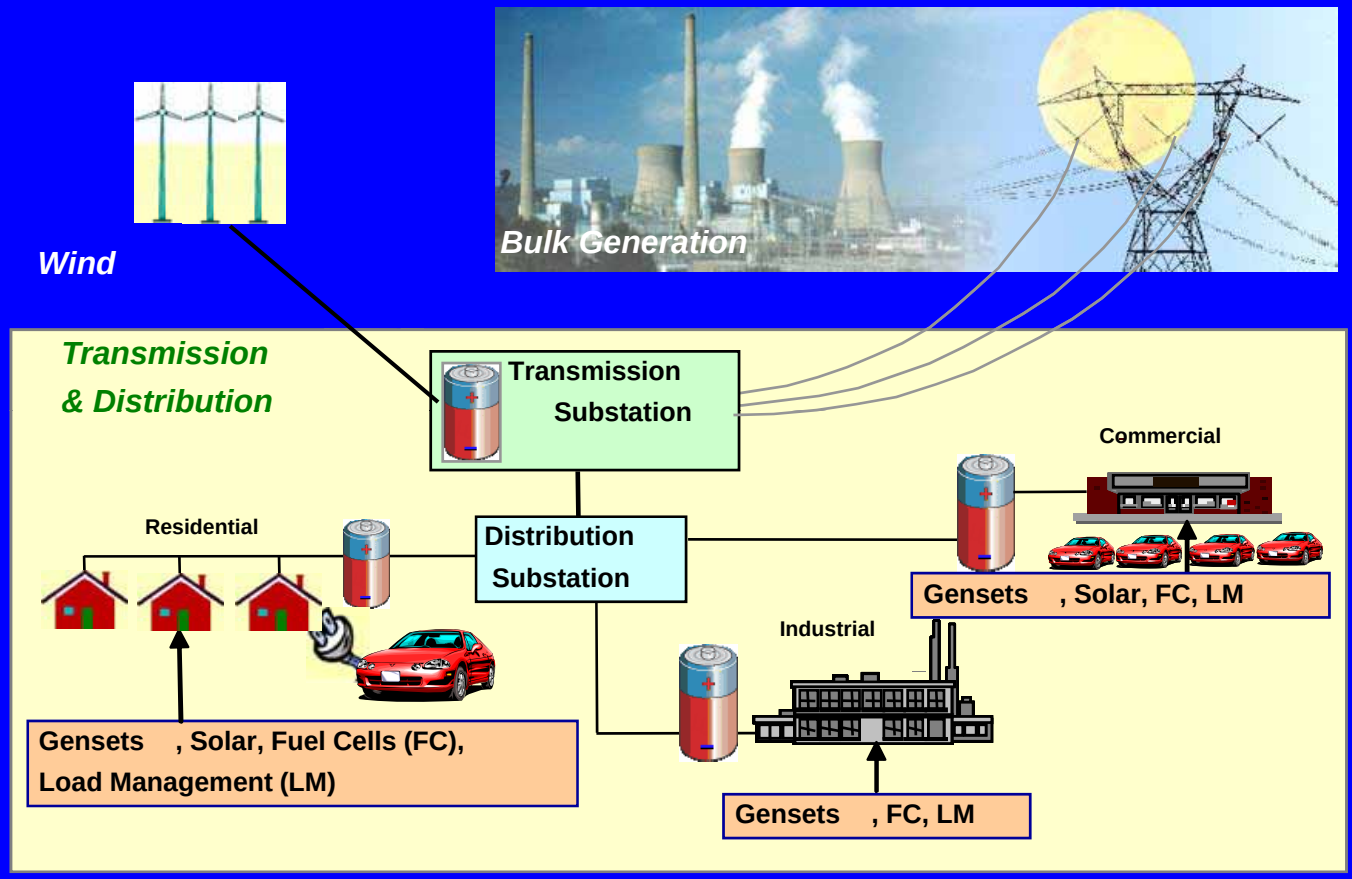
Energy Storage can:

Provide Power Quality
and Digital Reliability,

Bridge Outages Seamlessly,

Allow Load Following for DG, and
make Renewables Dispatchable

Provide Peak Shaving
and Transmission Upgrade Deferral



Nourai, AEP

Distributed Storage, Distributed Generation, and Distributed Intelligence will be essential for the Grid of the Future

Requirements for Storage Technologies in Utility Applications

- Cost, Cost, Cost!
- Reliability
- Lifetime
- Efficiency
- Environmental Acceptability
- Safety
- Compactness

Research Directions:

Improve Battery Energy Density ($C V^2 / 2$)

- Increase Surface Area of Electrodes
  Carbon Foam, Nanostructured Powders,
  Carbon Nanotubes
- Increase Voltage
  Aqueous electrolytes <2V
  Non-aqueous can be <6V
  taylored assymetric cations

Quantum Modeling of Dynamics

Improve Membrane characteristics

Decrease Manufacturing Costs

Develop Markets (Linkage with PHEV?)

See also http://www.sc.doe.gov/bes/reports/list.html
DOE-Off. of Science: Basic Research Needs for Energy Storage

CONCLUSIONS:

- Energy Storage can be an effective Tool for Utilities as well as Customers
- Storage Technology is developing more Options for more potential Applications
- The Importance of Storage is becoming increasingly Accepted

Energy Storage
is a Disruptive Technology
whose Adoption will induce a
Paradigm Shift
in the Entire Utility Industry
!!!

RESOURCES

http://www.sandia.gov/ess/

EPRI/DOE Energy Storage Handbook

ESA Annual Meeting (Anaheim, May, ’08)

DOE Prog. Rev. (DC, Oct. ‘07)