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ELECTRICAL ENERGY STORAGE FOR UTILITY SCALE APPLICATIONS

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Sandia National Laboratories

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!

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	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

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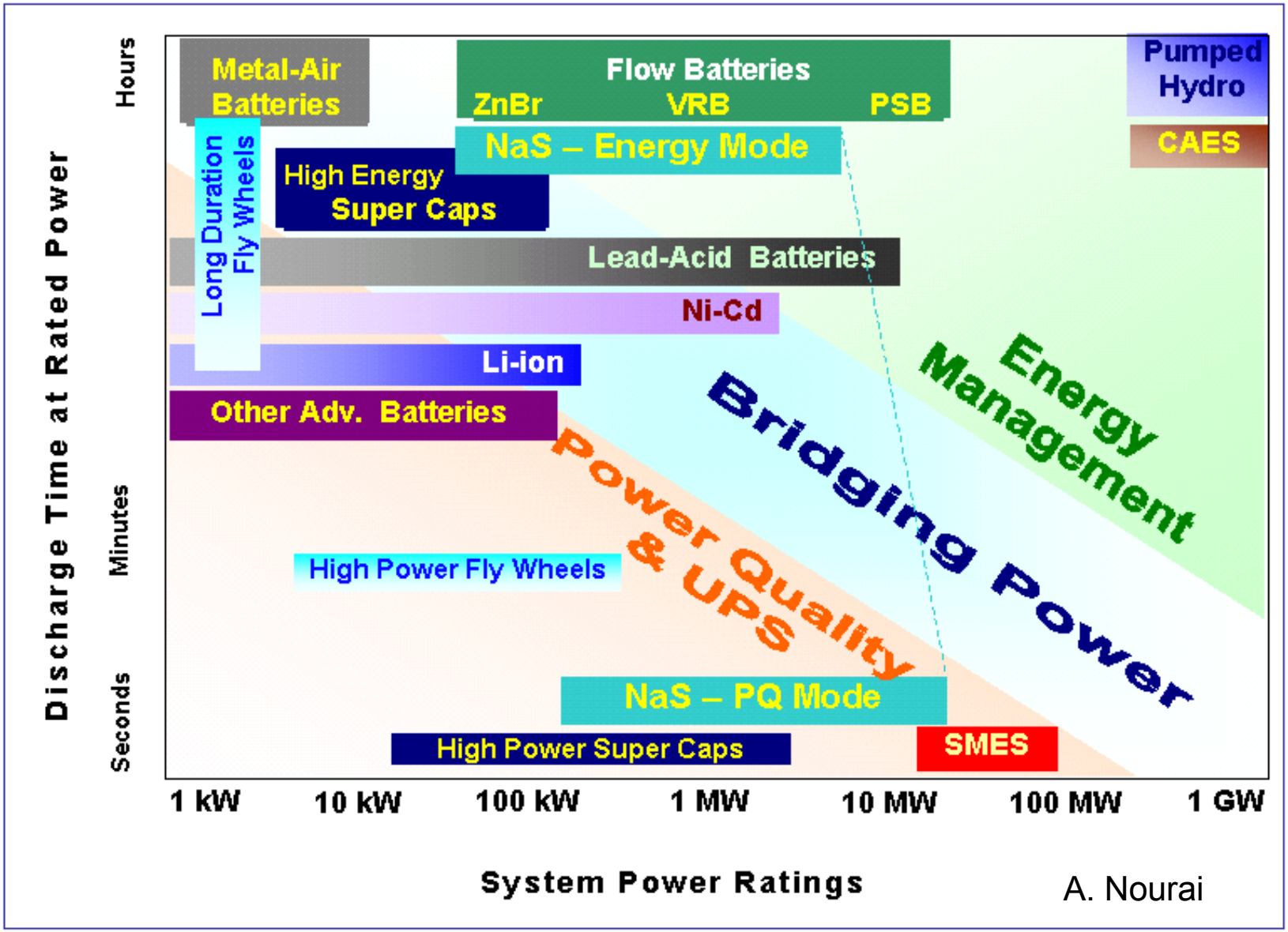
Storage Technologies and Regimes of Application



A. Nourai

RELIABILITY AND POWER QUALITY

Has Become a Necessity for the Digital Society

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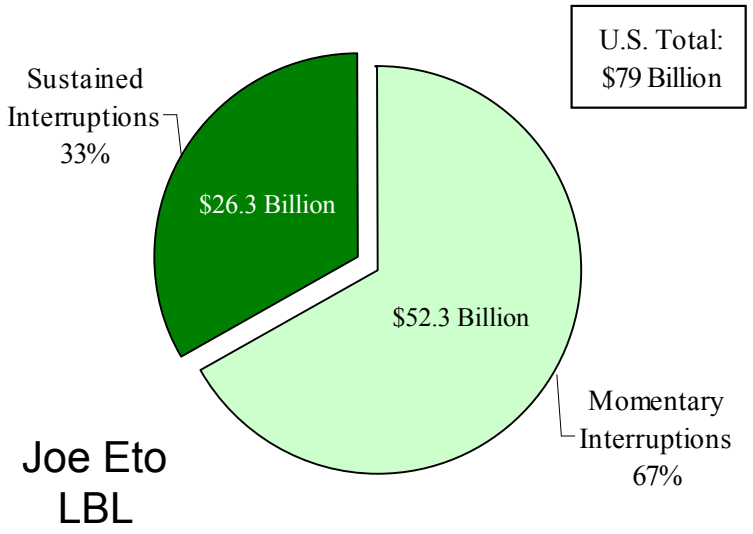
Outage Costs for U.S. Industry estimated at $79 Billion Annually in a recent study by Joe Eto, LBL

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



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

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Nine Nines of Reliability cannot be provided by Generation

Only Energy Storage can provide seamless Continuity of Power Supply

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L/A Battery for Power Quality and Reliability

12.5 MW - 30 sec System at Microchip Plant

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Ni-Cd Battery for Outage Support

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

Flywheels for Grid Frequency Regulation

A Beacon Flywheel being assembled

Containerized 7 Flywheel System

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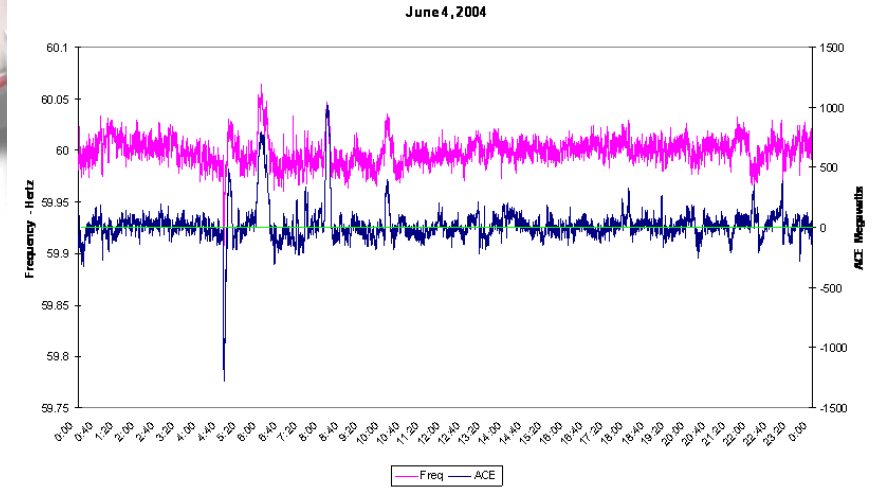

Frequency Fluctuations and ACE signal

CEC / DOE PROJECT:

Beacon Power 100 kW Flywheel System for Grid Frequency Regulation

A $600 million Market !

100 kW Installation at PG&E DUIT Facility
Responds instantaneously to CAISO Signal !

100 kW / 25 kWh per Flywheel
Is being built. DOE Funding for
20 MW facility Design

100 MVA could Eliminate 90% of
Frequency Variation in California!

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DG LOAD FOLLOWING

MICROGRIDS

RENEWABLE DISPATCH

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Load Management at a Remote Residence

5kW PEM fuel cell

11kW / 30kWh L/A

Battery follows variable Load to allow constant Output by Fuel Cell

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ULTRACAPS
FOR A 1.25 MW MICRO-GRID:

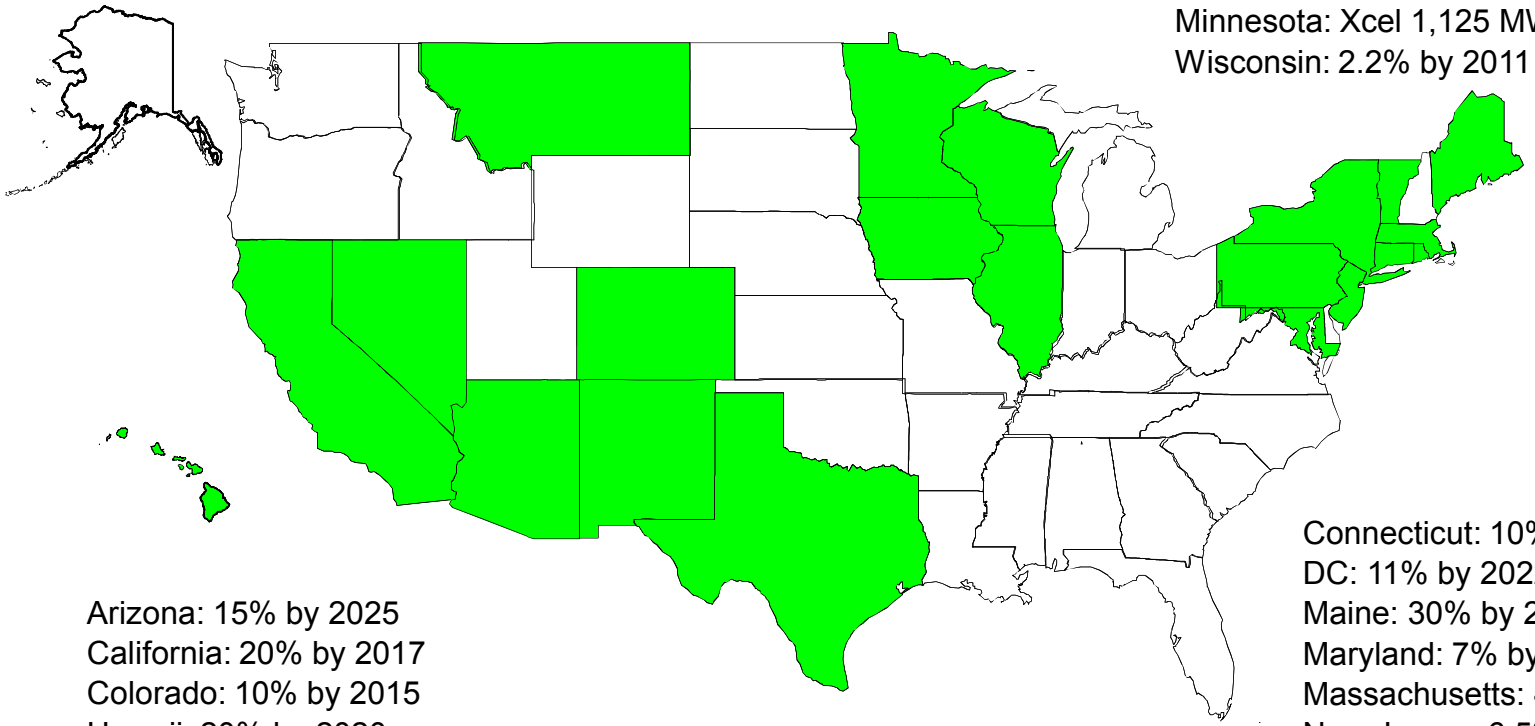
450 kW Maxwell EC-Capacitors to provide Wind Smoothing and Backup Power for the Palmdale, CA Water Treatment Plant
CEC / DOE PROJECT

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

Aggressive Renewable Portfolio Standards



Illinois: 8% by 2013
Iowa: 105 MW
Minnesota: Xcel 1,125 MW by 2010
Wisconsin: 2.2% by 2011

Arizona: 15% by 2025
California: 20% by 2017
Colorado: 10% by 2015
Hawaii: 20% by 2020
Montana: 15% by 2015
Nevada: 20% by 2015
New Mexico: 10% by 2011
Texas: 10,000 MW by 2025

Connecticut: 10% by 2010
DC: 11% by 2022
Maine: 30% by 2000
Maryland: 7% by 2008
Massachusetts: 4% new by 2009
New Jersey: 6.5% by 2008
New York: 25% by 2013
Pennsylvania: 18% by 2020
Rhode Island: 16% by 2009
Vermont=load growth 2005-2012

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Such Mandates can only be reached

if Renewables are smoothed

and made dispatchable

by Energy Storage

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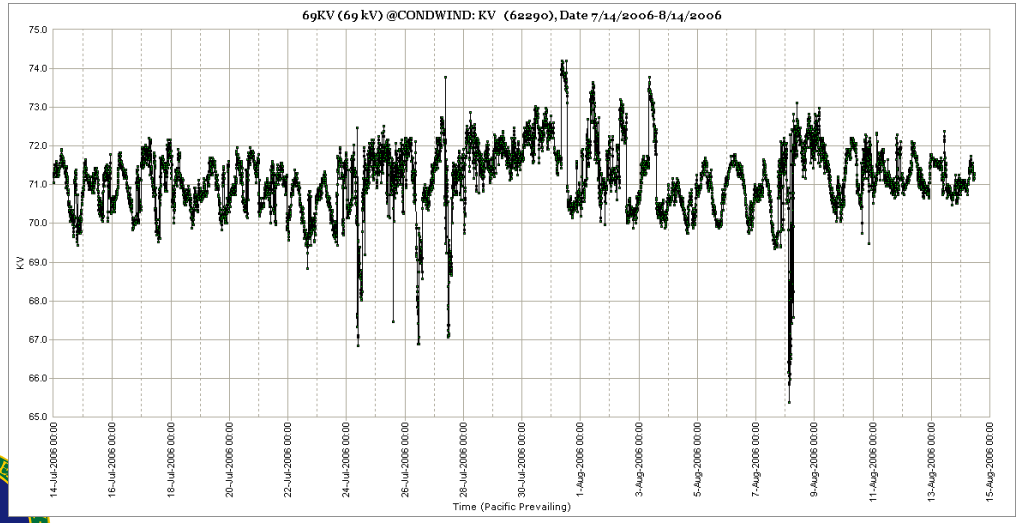
The BPA / DOE Wind Project:

To Smooth out Fluctuations from a 48 MW Wind Farm on the BPA Grid



Measured Wind Voltage
July 14-Aug.14, 06

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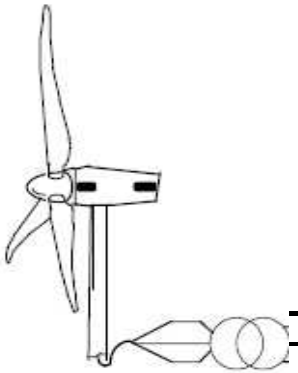
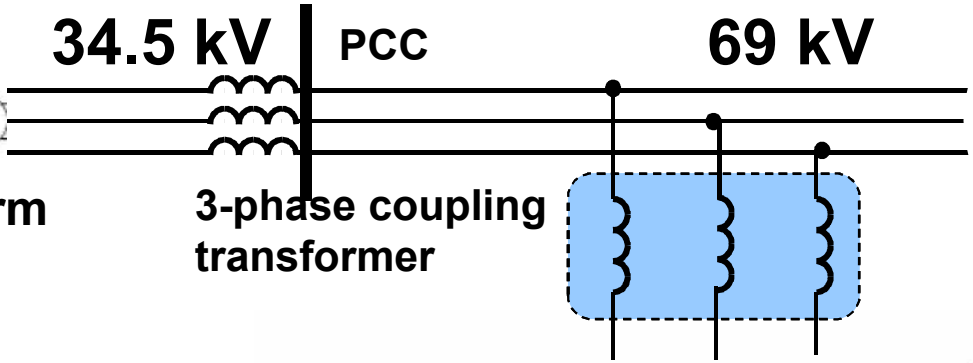
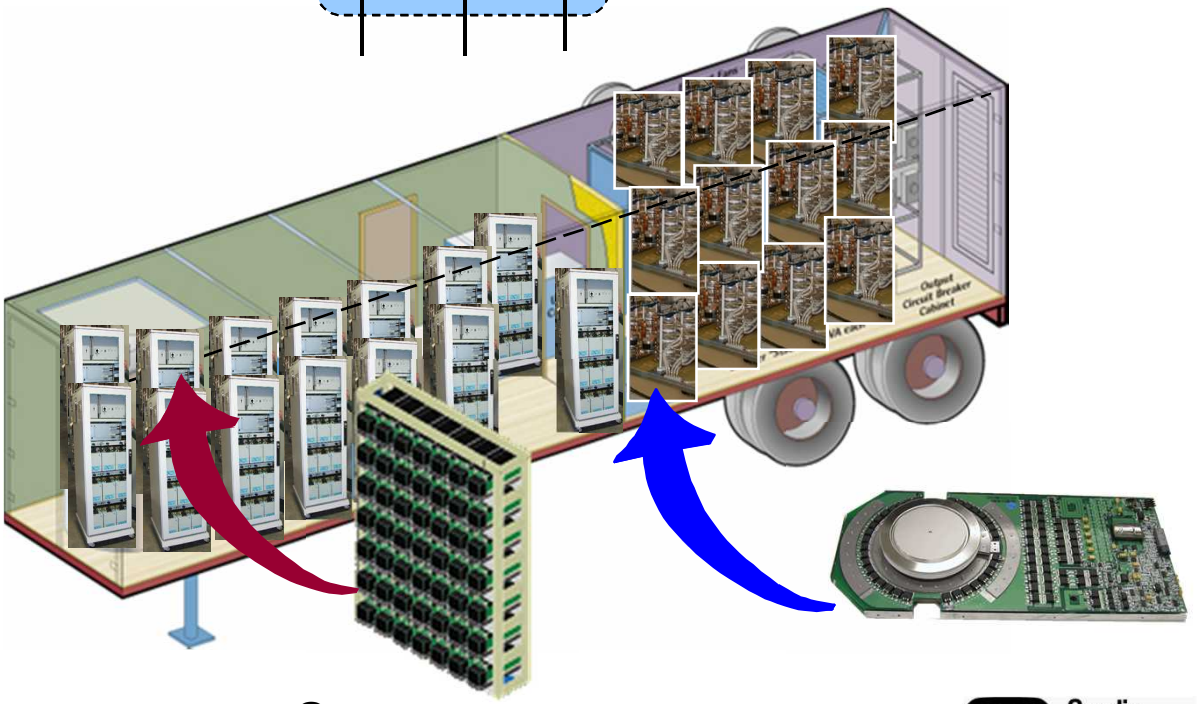
Wind Integration





Condon, OR Wind Farm
Weak grid
Pronounced PQ issues
10 MVA Statcom
BPA, DOE, TVA, EPRI
Prototype for smoothing
major contributions from
Wind and Wave Energy



Supercaps

ETO-Based Converter

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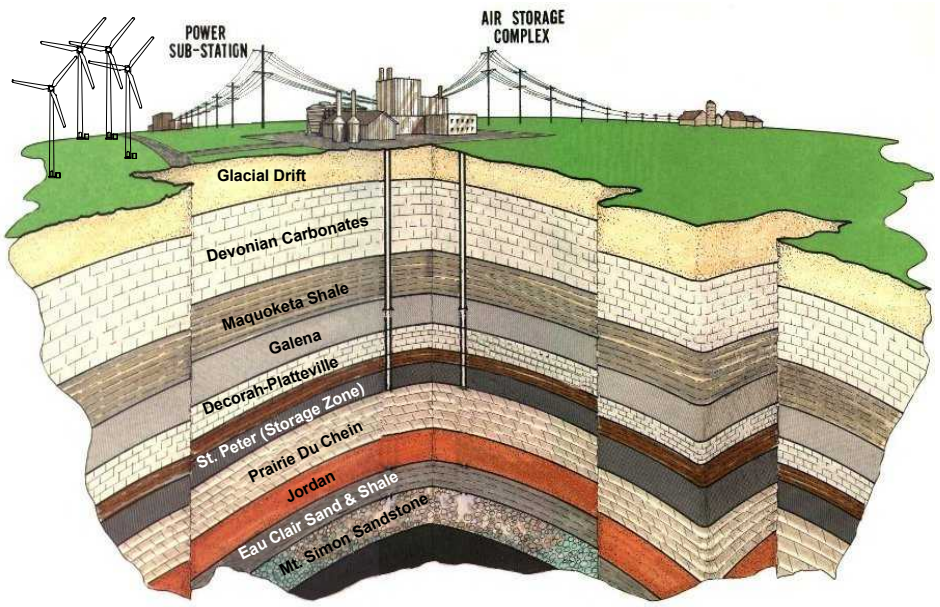
COMPRESSED AIR ENERGY STORAGE:

CAES in:

- Mined Caverns
- Salt Domes
- Aquifers



Inexpensive Off-Peak Power is used to Compress Air. On-Peak, Compressed Air is used as Input for GasTurbine Compressor, increasing Efficiency

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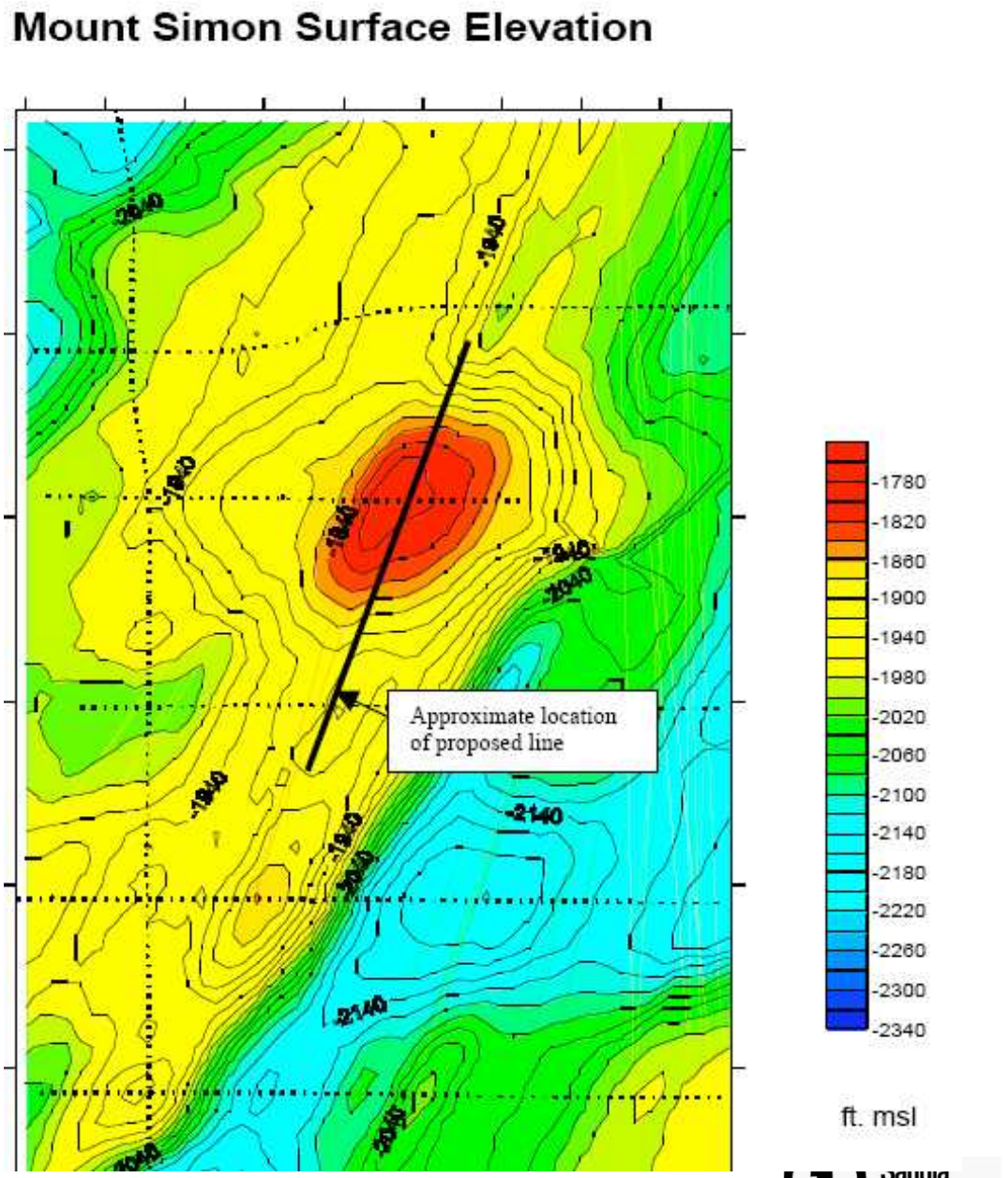
200 MW Aquifer Compressed Air Energy Storage (CAES) with 75 MW of Wind and off-peak Power

Found in Iowa:
A good Site
with a
a good aquifer

A DOE/ Iowa Muni Project



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PEAK SHAVING

ENERGY MANAGEMENT

UPGRADE DEFERRAL

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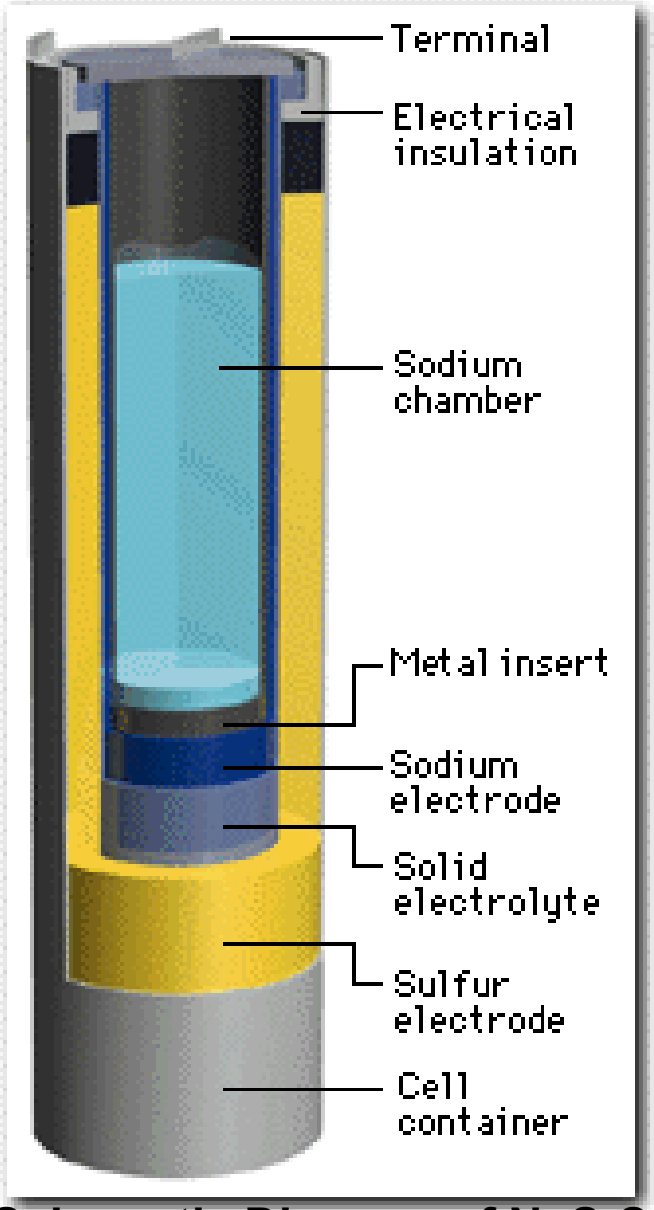
SODIUM-SULFUR (NAS) BATTERY

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



Schematic Diagram of NaS Cell

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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

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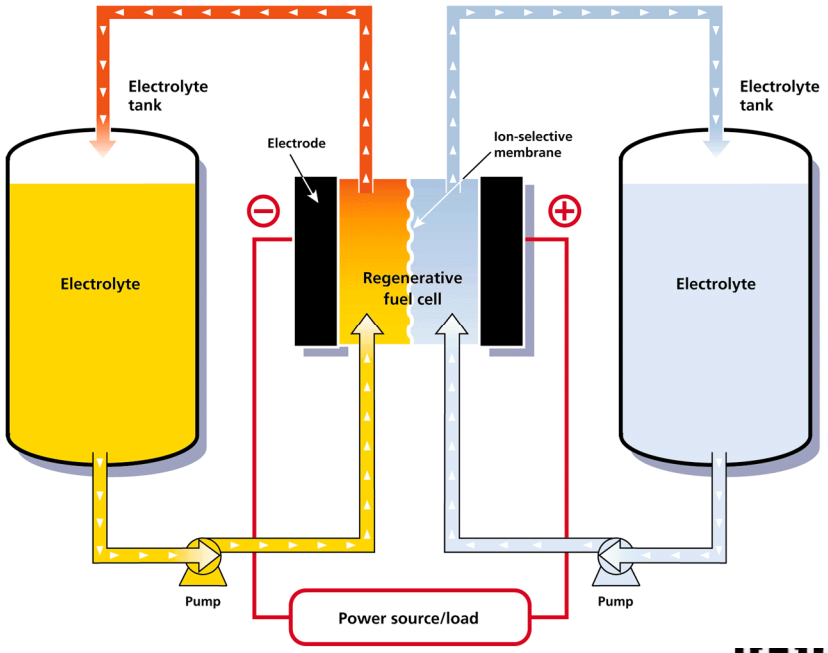
FLOW BATTERIES:

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

- Vanadium Redox
- Zinc-Bromine



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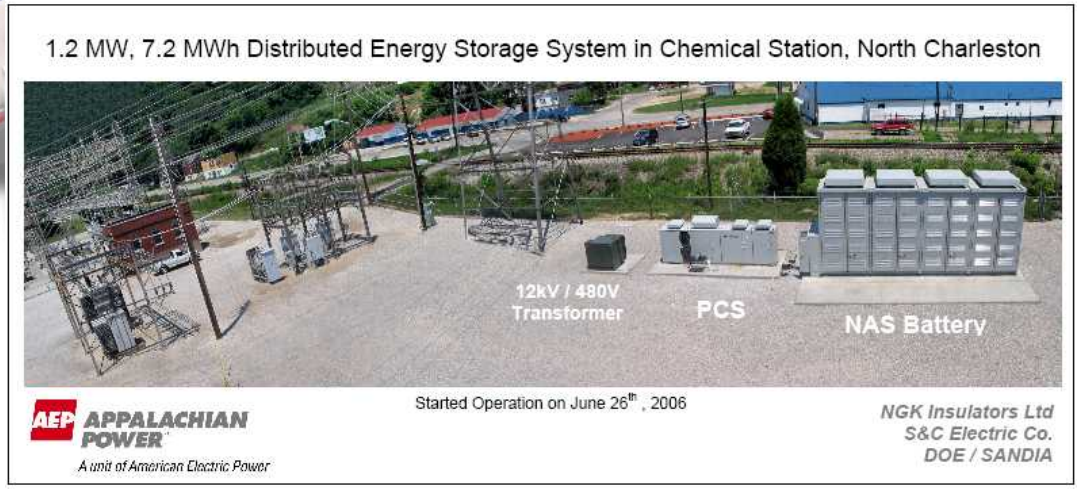
Vanadium Redox Battery at Rattlesnake #22

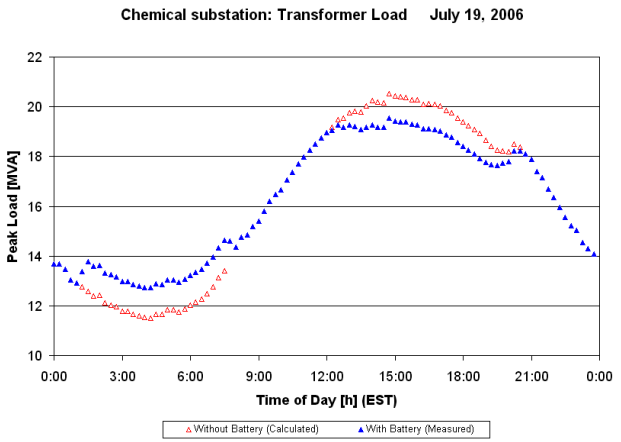
- Castle Rock, Utah, at the End of a 209 Mile 125kV Feeder
- Feeder too small for Peak Loads
- Complaints about Outages, PQ
- Upgrade costly and 3 year delay
- DG not acceptable for Pollution Reasons

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

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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

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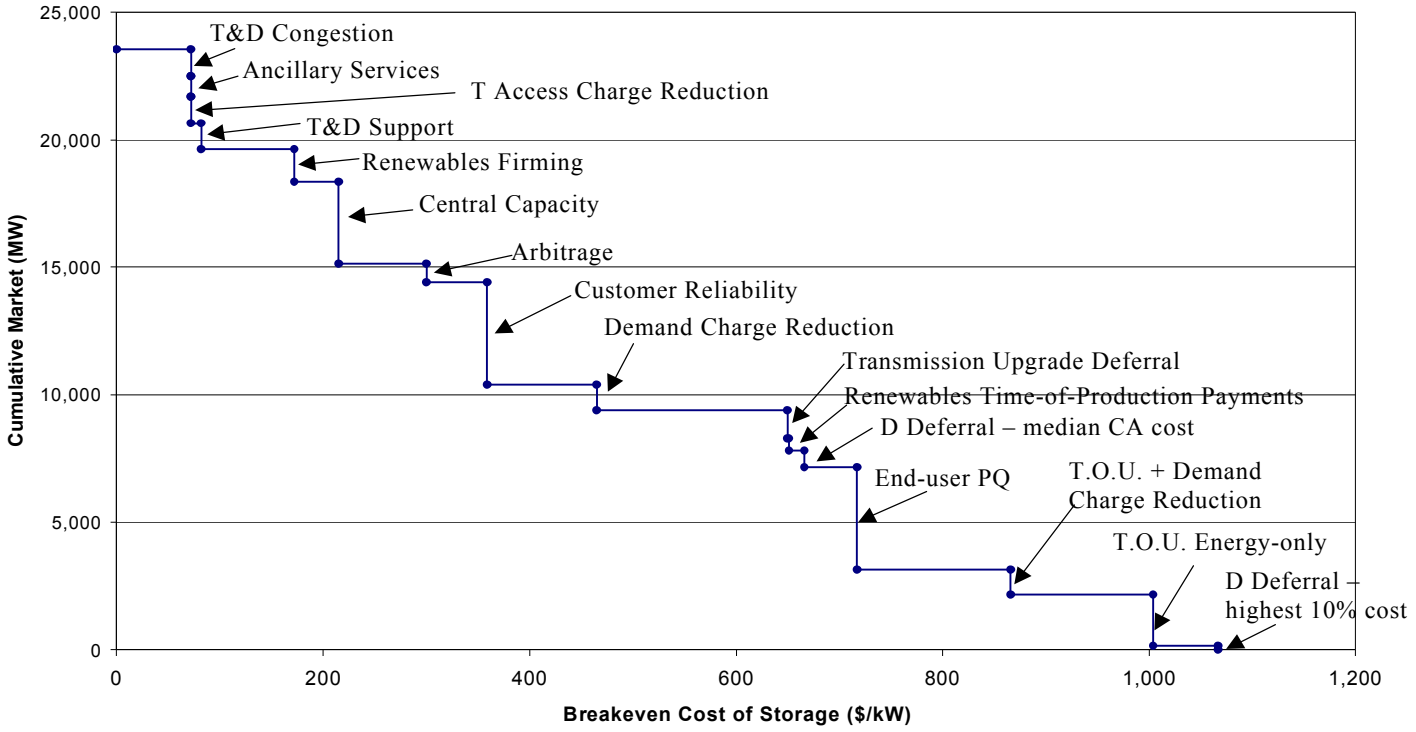
Storage Potential, California



U.S. = 8 x CA

single benefit!

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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

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

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RESOURCES

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

EPRI/DOE Energy Storage Handbook

ESA Annual Meeting **(Boston, May, '07)**

EESAT Meeting **(SF, Sept. 23-26, '07)**

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