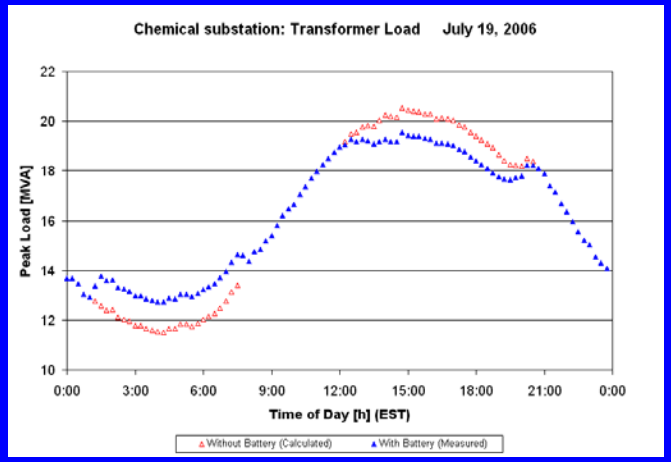
Energy Storage for Grid Resilience

IMRE GYUK, DIRECTOR,
ENERGY STORAGE RESEARCH, DOE-OE

Pumped Hydro	
Compressed Air Energy Storage (CAES)	PG&E
Aquifer CAES	Iowa
Advanced Isothermal	
Batteries	
NaS	AEP, PG&E
Flow batteries	
ZnBr	Primus
Vanadium Redox	UET, Vionx
Lead Acid	
Lead carbon	EastPenn
Aqueous hybrid ion	Aquion
Lithium Ion	SouCalEd, AES
Flywheels – Energy	Amber
– Power	Beacon
	Helix
Electrochemical Capacitors	



Charleston, WV Appalachian Power Substation

1.2 MW / 6hr NaS Battery for Substation Support:

- First Commercial Application in US.
- Provides Backup during Peak Load
- Deferred Upgrade for 3 Years
- Reduces Transformer Heat up
- Potential Arbitrage Benefits 10K/month

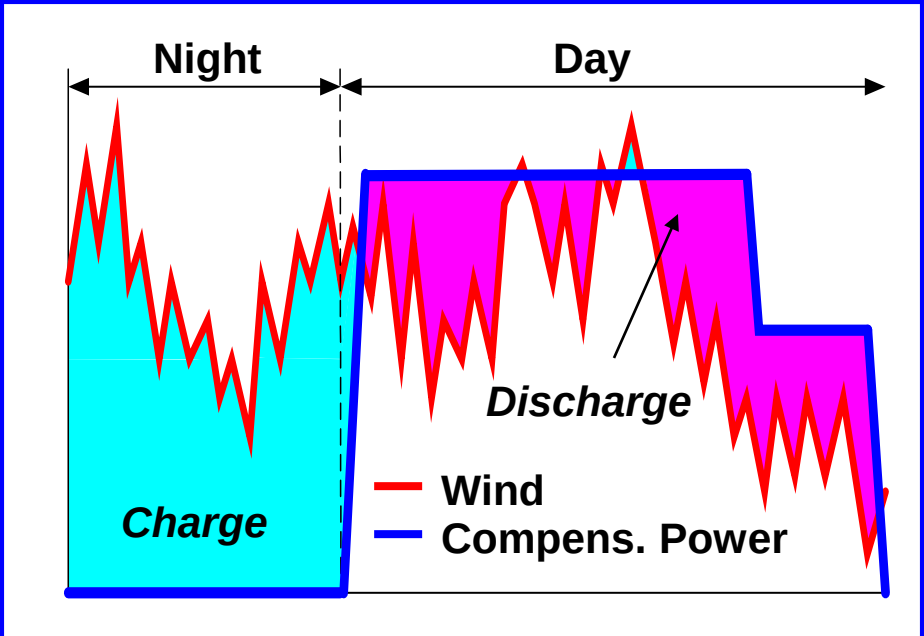
AEP / DOE PROJECT

Generic Design funded by DOE

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

Commissioned June 26, 2006

Rokkasho Windfarm in Northern Japan



Japan Target:

3,000 MW Wind by 2010

Rokkasho:

51 MW Wind

34 MW / 7 hr NaS Storage

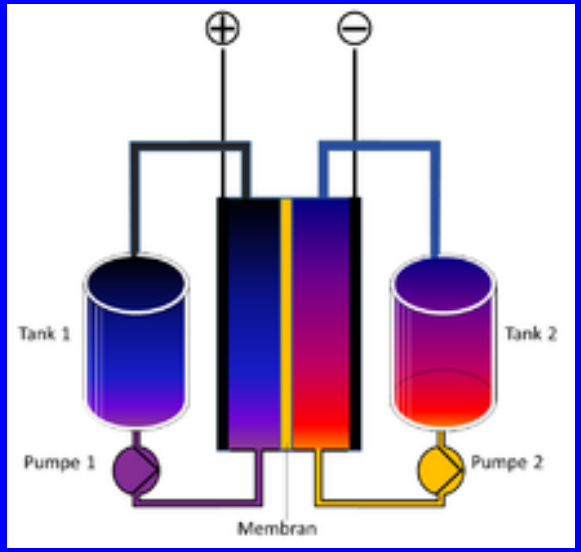
24 Hour Advance Planning depending on Wind and Load Forecast

Flow Batteries decouple Power from Energy:

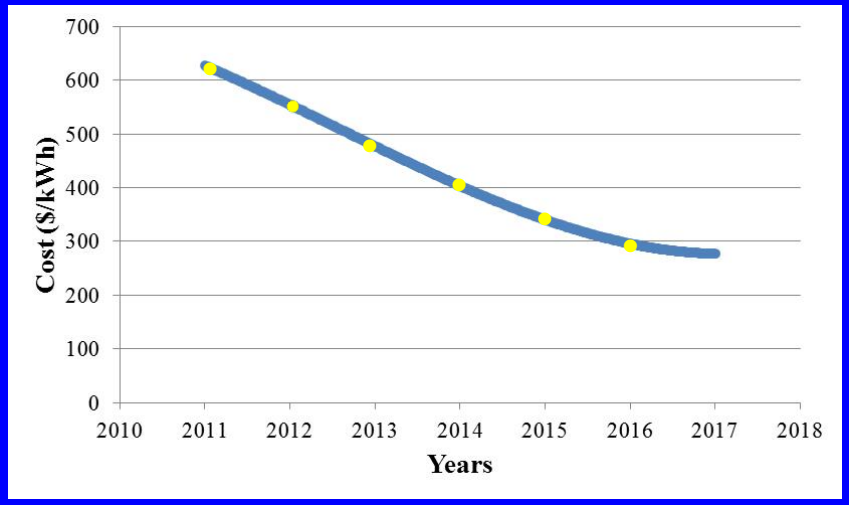
- Power is produced by a rechargable Electrochemical Cell
- Energy is stored in Tanks of electrolyte

This is analogous to a car:

- Power comes from the Engine
- Energy is in the gasoline Tank



Mixed Acid V/V Redox Flow Batteries, PNNL



3 Commercial Licenses
Award for Tech Transfer

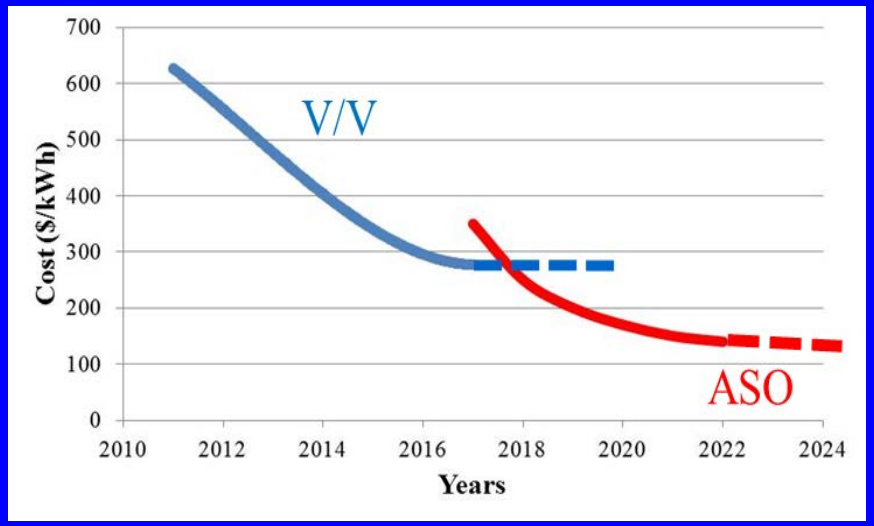
UniEnergy 600 kW/2.2MWh battery system

- Temperature stability + 80%
- Energy density + 70%
- Projected system cost of $300/kWh for 4 hour system

Some 22MW/88MWh in play

2017 EPA /ECS
Green Chemistry Challenge Award

Following consistent Performance Enhancement,
and Reduction of System Costs,
Redox Material and Membrane Costs now predominate.



Aqueous Soluble Organics:
Depend on Science,
not the Commodities Market!

- Low cost Material
- Earth Abundant
- Less Corrosive and Toxic

Phenazine/Ferricyanide demonstrated stable over 500 cycles.

PNNL Innovation Award at TechConnect 2016

Washington State Clean Energy Fund:

Solicitation for $15M for Utility Energy Storage Projects

Selected projects with UET vanadium flow battery:

- Avista (1MW / 4MWh) -- PNNL -- WA State U
- Snohomish (2MW / 8MWh) – PNNL -- 1Energy -- U of WA

Under a DOE / WA MOU, PNNL will participate in both projects, providing use case assessment and performance analysis.

Vanadium technology with 1.7x Energy density developed at PNNL for DOE

Ribbon Cutting
Avista, April 2015

2nd Solicitation: DOE Teaming with Avista on Transactive Microgrid

EXISTING CAES PLANTS:

HUNTORF, GERMANY (290 MW)

McINTOSH, ALAB. (110 MW)

McIntosh

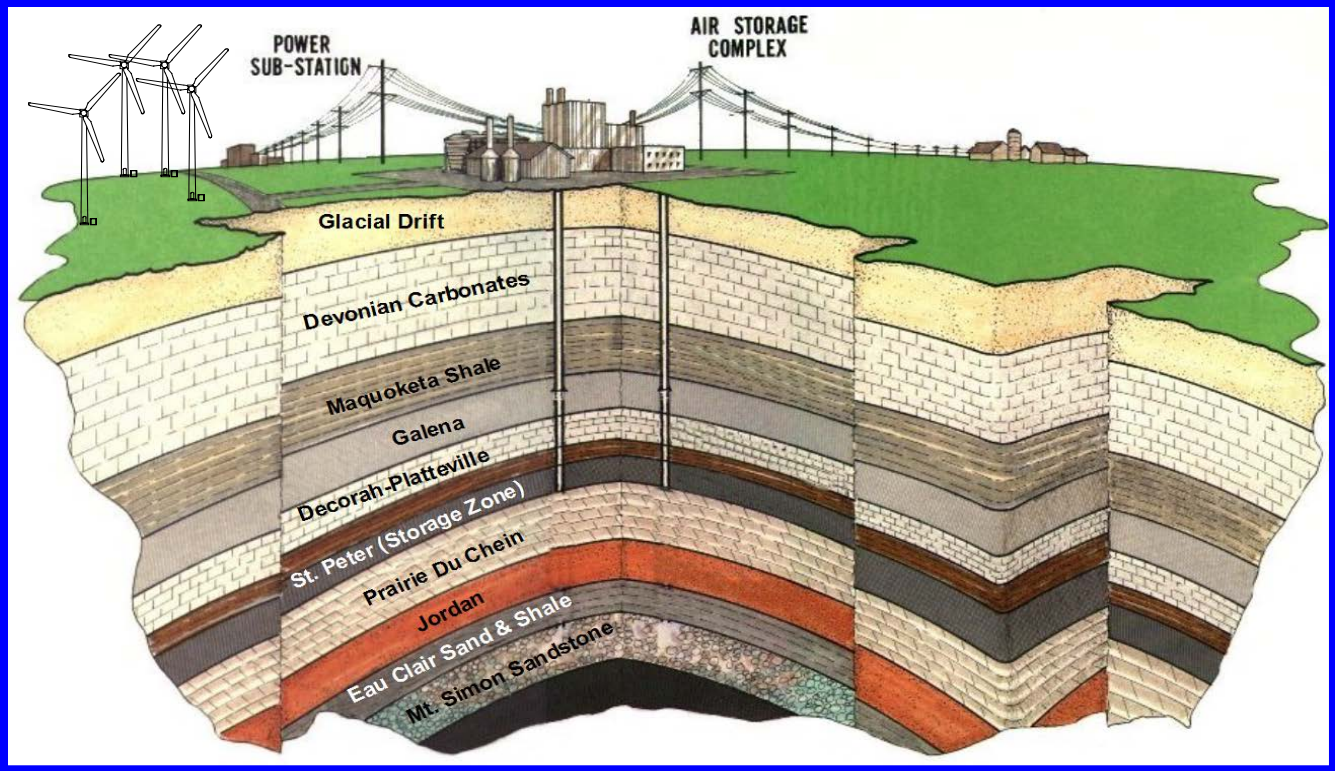
Huntorf

Compressed Air can be Stored in:

- Salt Domes
- Mined Caverns
- Abandoned Oilwells
- Aquifers
- Underwater

Extensive Research on Aquifer Storage conducted for DOE at PNL (ca. 1980)

DOE CAES Aquifer Test: Pittsfield, Ohio (1984) 10m X 200m Air Bubble in porous Sandstone



Underground Aquifer Storage

Iowa Associated Municipal Utilities and ISEP decide to install 200 MW of Aquifer Compressed Air Energy Storage (CAES) together with 75 MW of Wind and off-peak Power

DOE Provides $2.9 M in Funding for:

- Reservoir Investigation
- Market Research
- Subsurface Technology
- Wind Farm Project
- Alternate Fuel Study
- Power Project
- Sandia Technical Support

Site Selection:

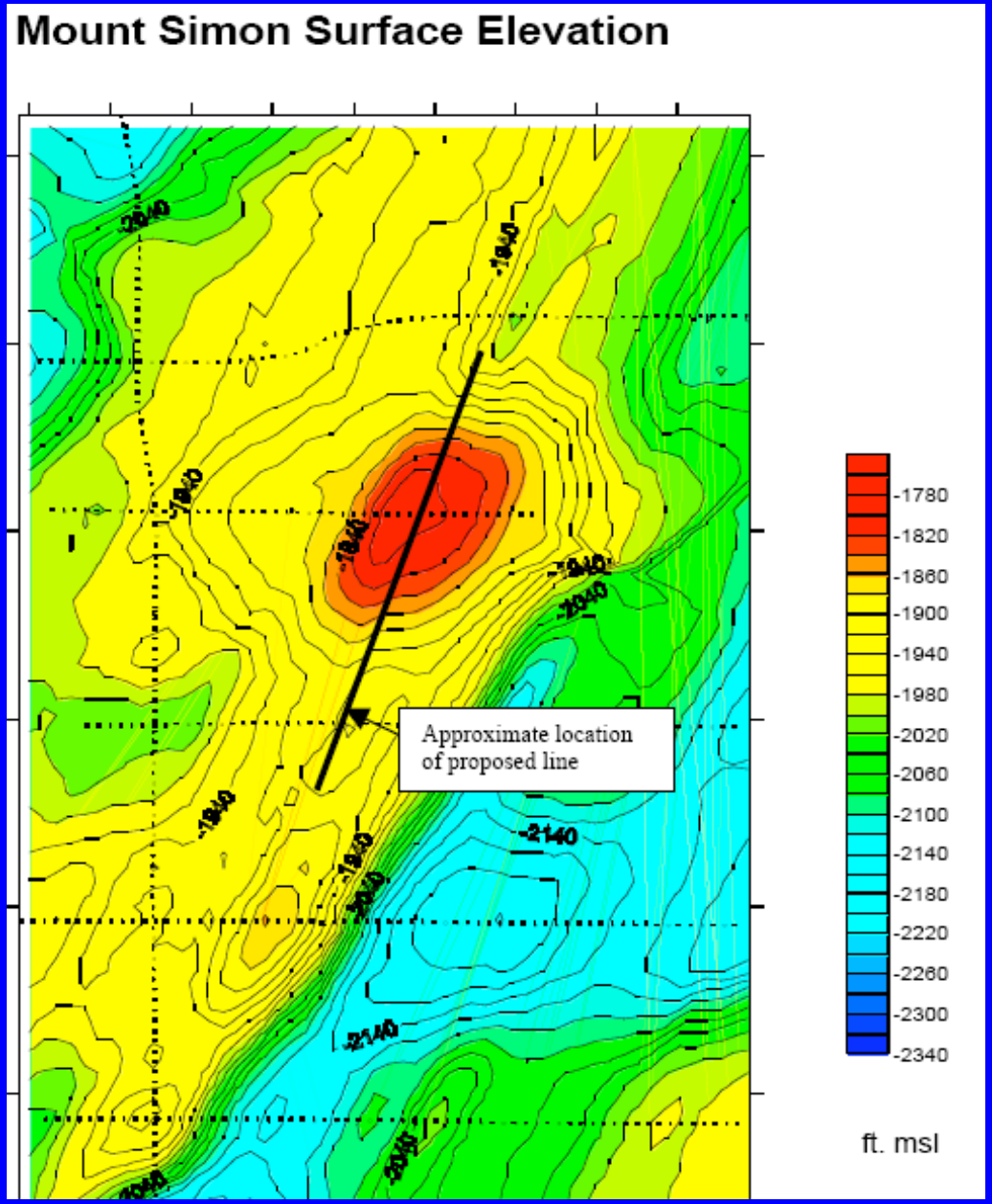
Seismic testing has established the general Conformation of the underground Formation: Mt. Symon

Data from a nearby Gas Well provides structural and hydrologic characteristics of Rock Strata.

Hydrogeologic Modeling, using these data, and calibrated against the gas well allows estimates of the effectiveness of the Aquifer for Storage

Found
after diligent
and extensive
Search:

A good Site
with a
A good aquifer!



ARRA - NYSEG:

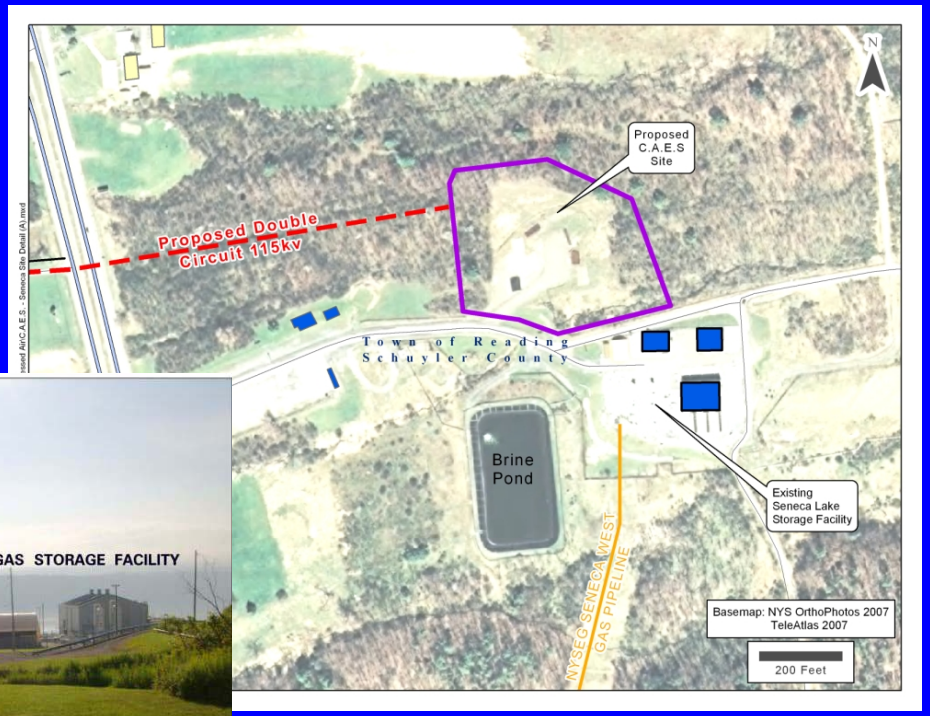
180 MW / 10hr Compressed Air Energy Storage Facility in Watkins Glen, NY

Layered Salt formation

Gas Pipe Line

Transmission Line

Installed Wind Generation



2 CAES Projects = 450MW in Stimulus Package!

Modular Undersea Compressed Air Energy Storage (UCAES) System

An SBIR Project by Brayton Energy, NH

- Constant Pressure
- Rigid Non-buoyant Containment
- Proposed Deployment: Hawaii

Hydrostor
Funded by Toronto Hydro
In service Nov. 2015

“There’s no reason why it shouldn’t work, but there are lots of reasons why it wouldn’t be economical,” says Imre Gyuk, Energy Storage Program Manager at the U.S. DOE. Smithsonian.com Jan. 6, 2016

Pumped Storage Hydro-Electric Power

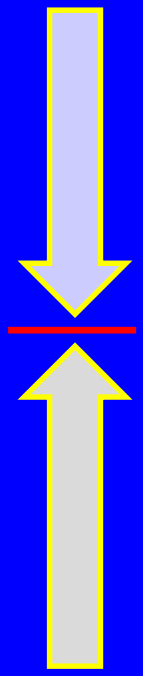
Ameren: Taum Sauk, Missouri,
440MW re-commissioned May, 2010

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

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

Magnum CAES: 160MW in UT

Storage Economics:



The **Cost** of a Storage System depends on the Storage Device, the Power Electronics, and the Balance of Plant

The **Value** of a Storage System depends on Multiple Benefit Streams, both monetized and unmonetized

LCOE depends on Application!

- Power Electronics 20-25%
- Energy Storage Device 25-50%
- Facility 20-25%

- Arbitrage
- Frequ. Reg.
- Dem. Charges month, year
- Resiliency