State & Federal Energy Storage Technology Advancement Partnership (ESTAP)

Todd Olinsky-Paul

Clean Energy States Alliance (CESA)

ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

- Information Exchange
- Partnership Development
- Joint Projects (National RPS Collaborative, Interstate Turbine Advisory Council)
- Clean Energy Program Design & Evaluations
- Analysis and Reports

CESA is supported by a coalition of states and public utilities representing the leading U.S. public clean energy programs.

Clean Energy States Alliance

Sandia National Laboratories

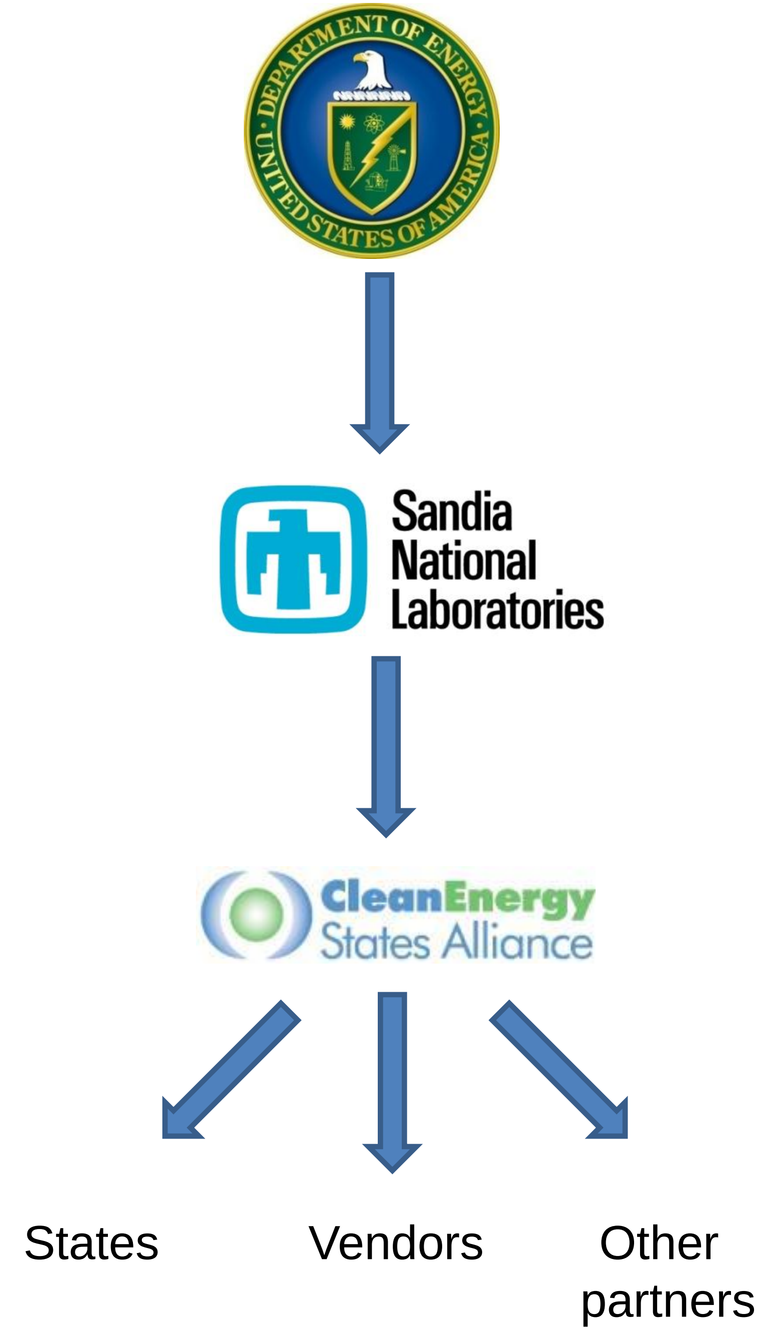
U.S. DEPARTMENT OF ENERGY

ESTAP* Overview

Purpose: Create new DOE-state energy storage partnerships and advance energy storage, with technical assistance from Sandia National Laboratories

Focus: Distributed electrical energy storage technologies

Outcome: Near-term and ongoing project deployments across the U.S. with co-funding from states, project partners, and DOE



* (Energy Storage Technology Advancement Partnership)

ESTAP Key Activities

1. Disseminate information to stakeholders

    - ESTAP listserv >500 members
    - Webinars, conferences, information updates, surveys

2. Facilitate public/private partnerships at state level to support energy storage demonstration project development

    - Match bench-tested energy storage technologies with state hosts for demonstration project deployment
    - DOE/Sandia provide $ for generic engineering, monitoring and assessment
    - Cost share $ from states, utilities, foundations, other stakeholders

Clean Energy States Alliance | Sandia National Laboratories | U.S. Department of Energy

Today's Guest Speakers

Veronica Szczerkowski, CT DEEP

Imre Gyuk, DOE Office of Electricity

Matt Lazarewicz, Consultant

Dan Borneo, Sandia

Contact Information

Project website: www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/

CESA Project Director: Todd Olinsky-Paul (Todd@cleanegroup.org)

Sandia Project Director: Dan Borneo (drborne@sandia.gov)

Thank You: Dr. Imre Gyuk, U.S. Department of Energy, Office of Electricity Delivery and Energy Reliability

Microgrid Grant and Loan Pilot Program Update
November 7, 2012

Connecticut Department of
ENERGY &
ENVIRONMENTAL
PROTECTION

Microgrid Grant and Loan Pilot Program

- Introduction
- Project Feasibility Application released on November 5, 2012
- PFA used to determine which projects are technically feasible
- Application deadline: January 3, 2013

Microgrid Grant and Loan Pilot Program – PFA Details

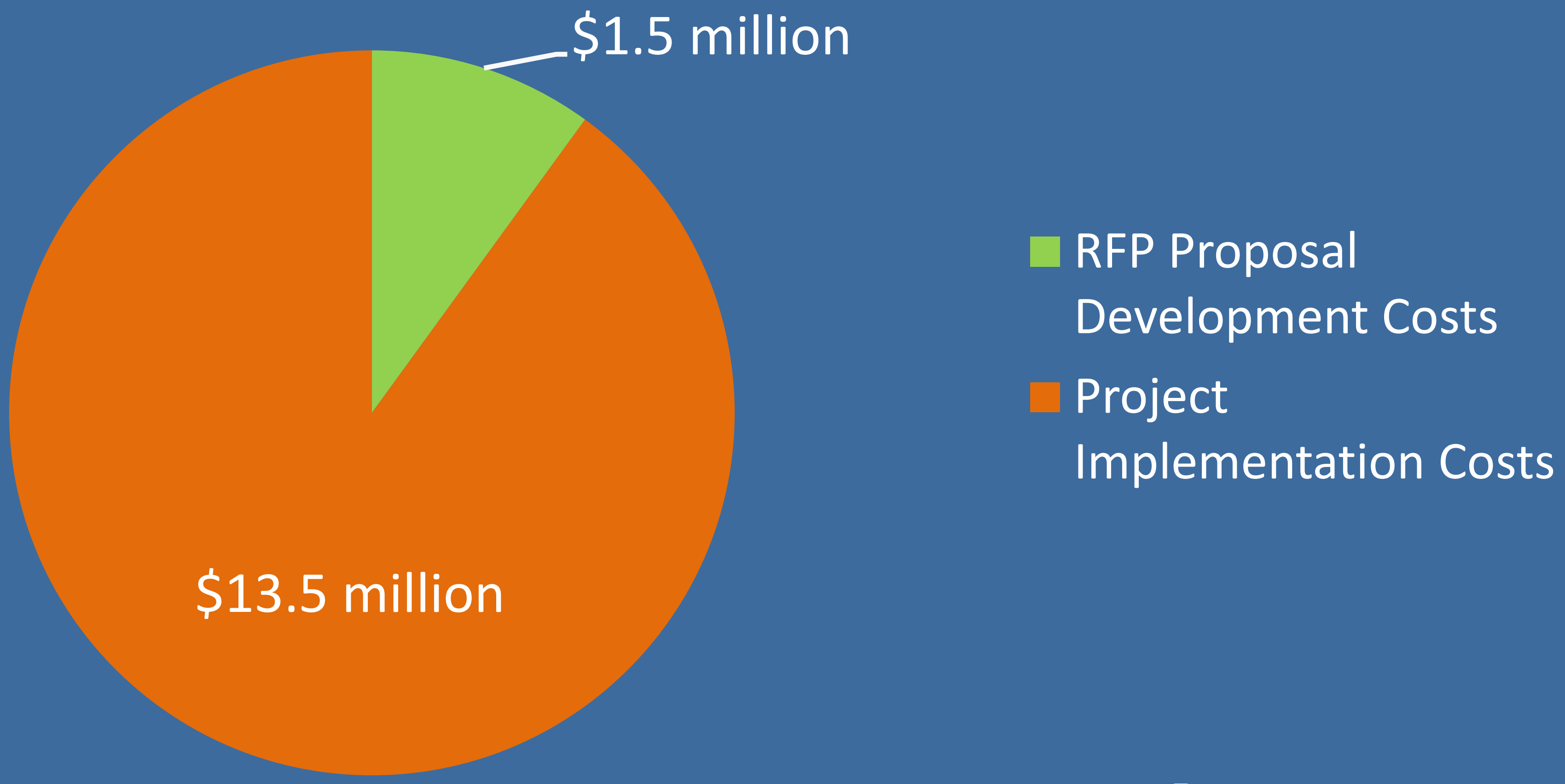
- Expanded Critical Facilities definition
- Additional Critical Facilities characteristics
- Municipality support for proposed Microgrid
- Include forms and diagrams in Application
- RFP guidance

Microgrid Grant and Loan Pilot Program – RFI Responses

- Considered in PFA development
- Identified regulatory, legal and funding issues
- Feasibility evaluation costs
- Application development costs

Microgrid Grant and Loan Pilot Program – Funding

$15 million to be awarded



Microgrid Grant and Loan Pilot Program

- Contact information:
  - Veronica.Szczerkowski@ct.gov

Thank you!

Energy Storage for the Electric Grid: Greener, Cleaner, Reliable

IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE

Energy Storage provides Energy

when it is needed

just as Transmission provides Energy

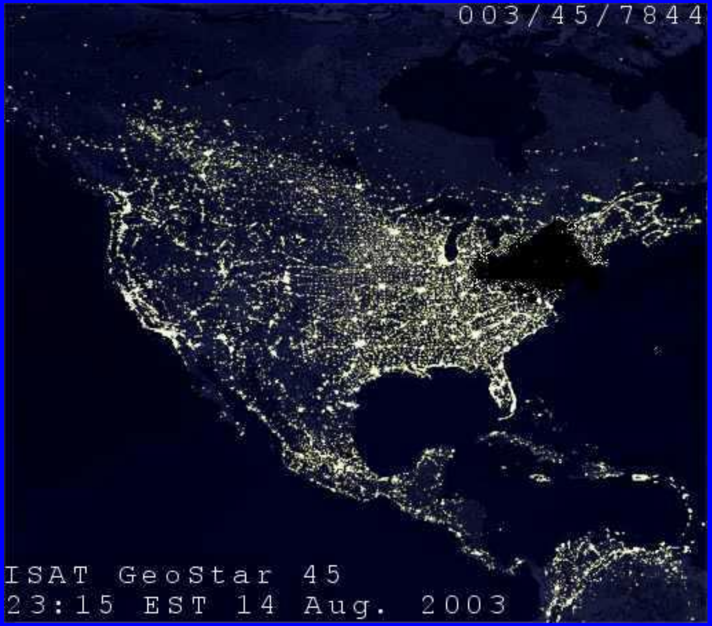
where it is needed

The U.S. Electric Grid
A Technological Marvel!

An Unbuffered, Stressed Complex System is inherently Vulnerable to Collapse

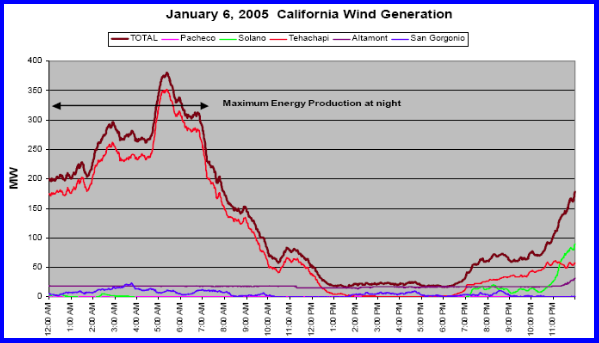
U.S. Aug. 14, 2003: 55M people
India, July 2012: 670M people

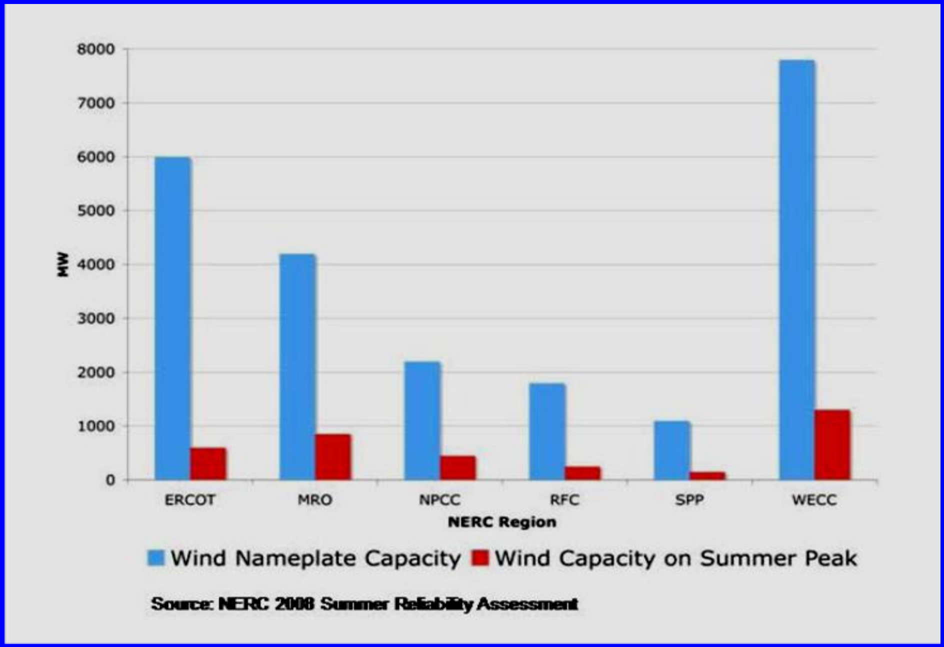
An Increasing Reliability Threat!



29 U.S. States have Renewable Portfolio Standards (RPS) Requiring 10-40% Renewables

On Peak Wind - the Reality!





Cost effective Energy Storage yields better Asset Utilization!

Non-Hydro Storage is becoming a Reality!

Some Large Storage Projects

27MW / 7MWh	1995	Fairbanks, AL
34MW / 245MWh	2008	Rokkasho. Japan
20MW / 5MWh	2011	Stephentown, NY
32MW / 8MWh	2011	Laurel Mountain, WV
14MW / 63 MWh	2011	Hebei, China
8MW / 32MWh	2012	Tehachapi, CA
25MW / 75MWh	2013	Modesto, CA

Worldwide (CNESA)

2011 May	370MW
2011 Aug.	455MW
2011 Nov.	545MW
2012 Feb.	580MW
2012 Apr.	590MW
2012 June	605MW
2012 Sept.	615MW

Beacon Flywheels

AES / A123 - Laurel Mountain

SoCal Edison / A123

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

A ten-fold Increase in Power Scale!

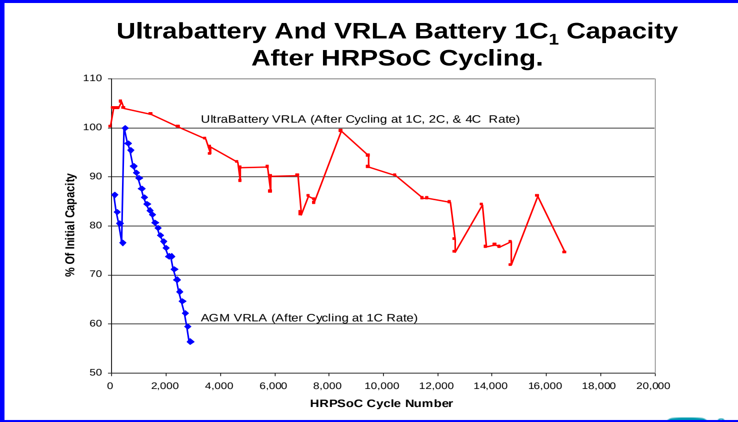
Large Battery System (3 projects,53MW)
Compressed Air (2 projects, 450MW)
Frequency Regulation (20MW)
Distributed Projects (5 projects,9MW)
Technology Development (5 projects)

533MW - $585M Costshare!

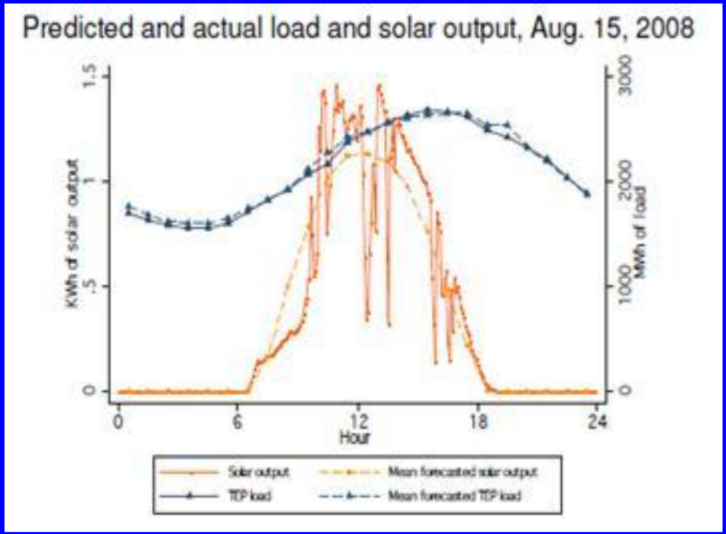
Medium Size Projects: 1-5 MW

ARRA – Public Service NM:

500kW, 2.5MWh for smoothing of 500kW PV installation; Using EastPenn Lead-Carbon Technology



PbC Testing at Sandia



Load & PV Output in Tucson, AZ

Commissioned Sep. 24, 2011 Integrator: Ecoult

ARRA – EastPenn, PA:

3MW Frequency Reg for PJM
1MW 1-4hrs Load Management
during Peak Periods

Commissioning June 15, 2012   Integrator: Ecoult

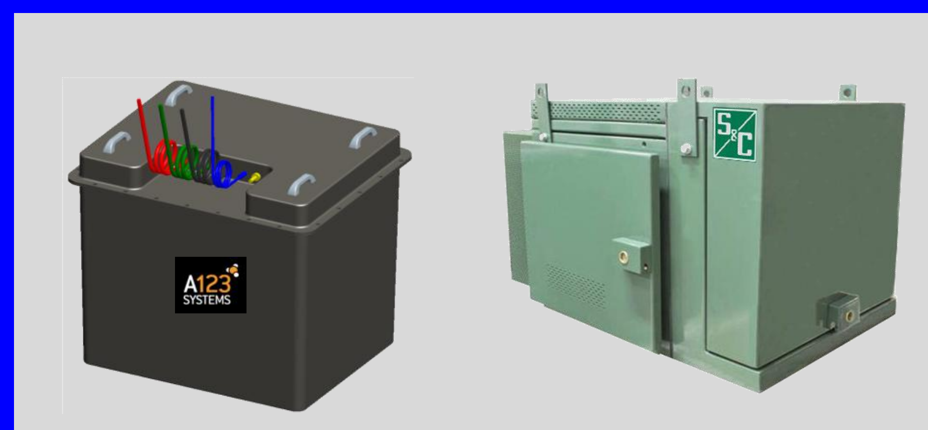
System is on line and drawing revenue!

S. Miksiewicz, CEO

Detroit Edison, ARRA Community Energy Storage Project

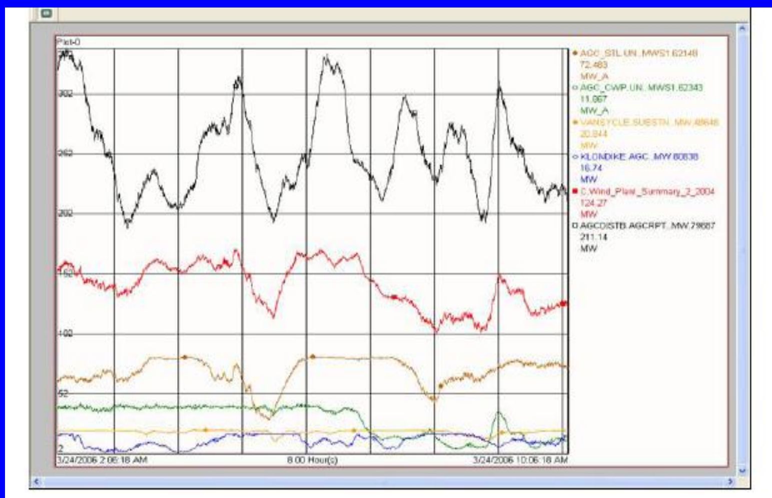
20 Units
each 25kW / 2hr
Coupled with 500kW PV
and 500kW / 30min Storage

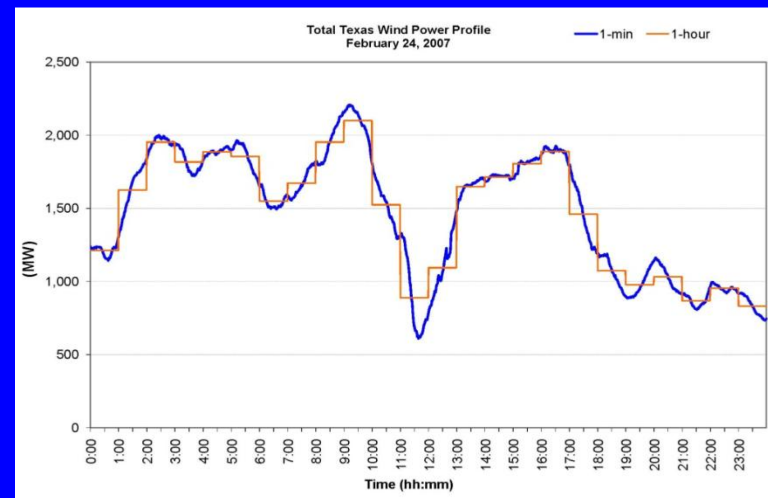
Monrovia County
Community College



Dow Kokam Battery S&C Inverter

Large Batteries for Wind Integration





Coincident BPA Wind Ramps BPA = 777,000 km^2
Texas = 696,000 km^2 Taiwan = 36,000 km^2

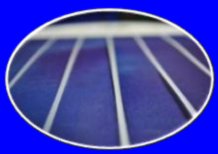
Feb. 24, 2007: 1,500MW / 2.hr; 30x Spotprices
NREL: Δ = 25% @ 2days, Δ = 50% @ 1 week

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

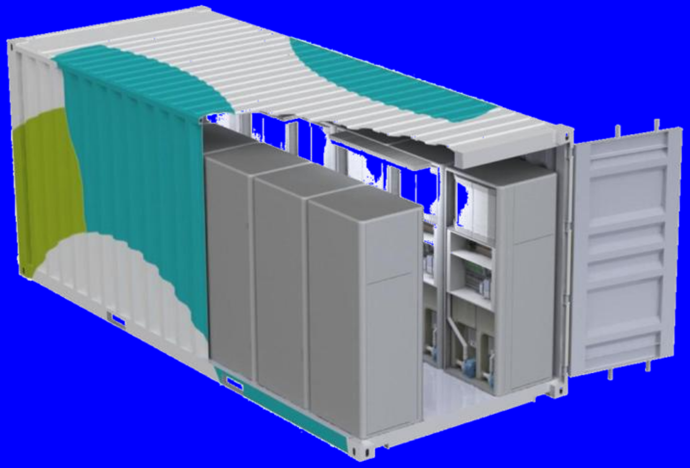
ARRA – Primus Power

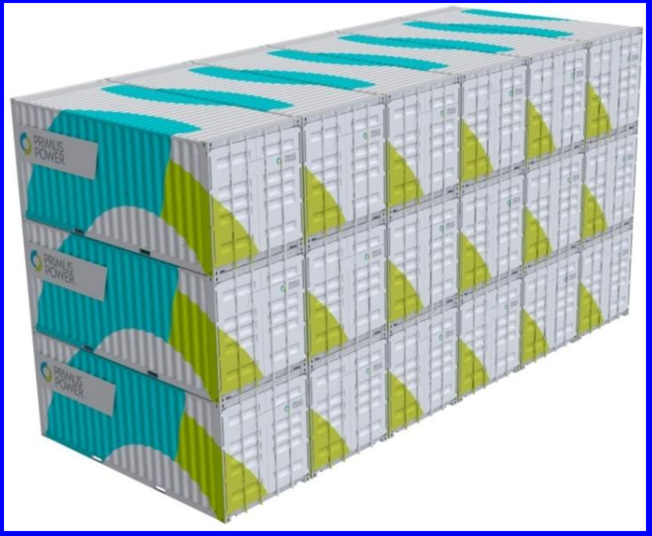
2012-TiE50
Hottest Tech Startups
2011-GoingGreen Global 200

25 MW / 3hr battery plant to firm 50MW of wind for the Modesto Irrigation District in CA, providing equivalent flex capacity to 50 MW of natural gas engines costing $73M



High power
metal electrodes





Fully self-contained, hermetically sealed flow battery modules

250kW/750kWh EnergyPods™

4MW/12MWh incremental “Plug & Play” deployment

ARRA – Duke Energy / Xtreme Power

36MW / 40 min battery plant

Ramp control, wind smoothing

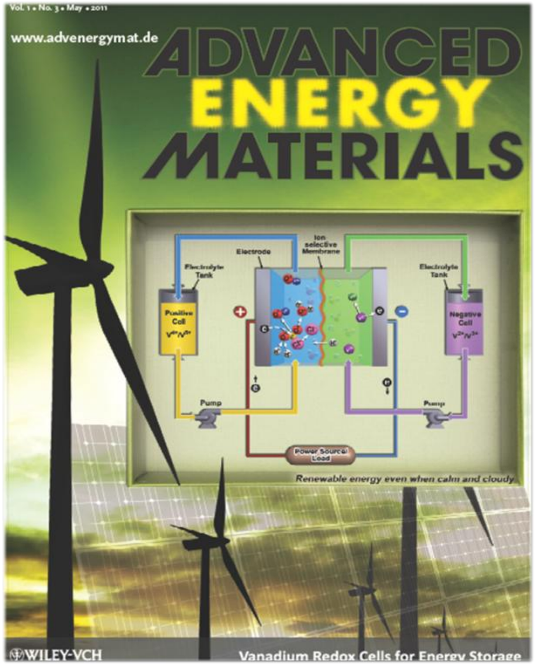
Linked to 153MW
Wind farm
at No-Trees, TX

AES, Laurel Mountain, WV - 32 MW Storage
Footprint <1 acre, no emissions
Integrated with 98MW Wind Farm

PNNL, Nov. 2011

Anderson *et. al.* Synthesis of Ionic Liquids Containing Cu, Mn, or Zn Coordination Cations

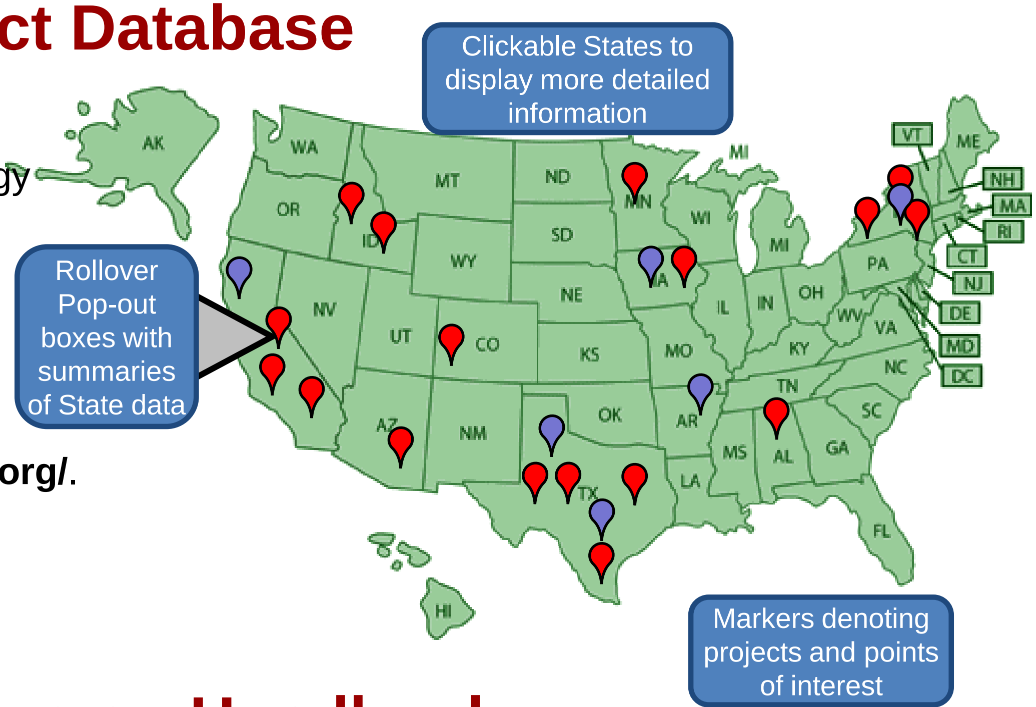
Sandia, Nov. 2011



Liyu Li *et al.*, Stable Vanadium Redox Flow Battery with High Energy; 1, 394-400, 2011

Energy Storage Project Database

A publicly accessible database of energy storage projects world-wide, as well as state and federal legislation/policies



http://www.energystorageexchange.org/.

DOE/EPRI Energy Storage Handbook

Partnership with EPRI and NRECA to develop a definitive energy storage handbook:

- Details the current state of commercially available energy storage technologies.
- Matches applications to technologies
- Info on sizing, siting, interconnecting
- Includes a cost database

SNL Energy Storage System Analysis Laboratory

Reliable, independent, third party testing and verification of advanced energy technologies from cell to MW scale systems

Expertise to design test plans for technologies and their potential applications

Cell, Battery and Module Testing

- Testers to accommodate a wide range of testing applications including:
  - 14 channels from 36 V, 25 A to 72 V, 1000 A for battery to module-scale tests
  - Over 125 channels; 0 V to 10 V, 3 A to 100+ A for cell tests

72 V 1000 A Bitrode (2 Parallel Channels)

Energy Storage Test Pad (ESTP)

System Testing

- Scalable from 5 KW to 1 MW, 480 VAC, 3 phase
- 1 MW/1 MVAR load bank for either parallel microgrid, or series UPS operations
- Subcycle metering in feeder breakers for system identification and transient analysis
- Can test for both power and energy use cases

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The DOE Storage Program has a Long History of working with the States

- CEC –DOE MOU on Storage initiated California's involvement in Storage
- CEC-NYSERDA MOU introduced NY to Storage
- DOE collaborates with BPA on 3 Projects
- Collaboration with Military on state side bases
- DOE works with Alaskan Native Villages
- State of Connecticut DEEP

Collaboration with Clean Energy States Alliance

- Webinar Series on Policy Issues related to Energy Storage
- Provide information on technical aspects of Energy Storage Systems
- Identify regulatory challenges to increased Storage System deployment
- Suggest possible responses/solutions to challenges
- Develop model PUC submissions requesting approval of rate base addition
- Advisory Committee comprised of industry and government experts

Our Goal is to make

Energy Storage

Ubiquitous

on the Electric Grid!!

RESOURCES:

www.sandia.gov/ess

www.electricitystorage.org

ESA Meeting, May 20-22, Santa Clara

EESAT, October 2013, San Diego

ESTAP Webinar:

Energy Storage Solutions for Microgrids

Matt Lazarewicz
Dan Borneo
November 7, 2012

Thanks !

- **DOE Office of Electricity**
- **Dr. Imre Gyuk PM Electricity Storage Program**

Objectives

- Energy Storage: The Practical Introduction
  - What is storage?
  - Types of storage
- What is a Microgrid & how storage fits in
- Islanding issues
- Storage makes generation behave like a hybrid vehicle
- Is storage expensive?
- Useful storage resources

Should storage be treated as a renewable? Absolutely!

Storage – Everywhere Around Us

- Automobile gas tanks
- Cash
- Parking lots
- Wood piles for fireplaces
- Computer memory
- Hot water heaters
- File cabinets
- Hotels
- To Do lists
- Shopping carts

What about the Power Grid?

US Department of Energy Viewpoint

Energy Storage provides Energy

when it is needed

just as Transmission provides Energy

where it is needed

Progress in Energy Storage Applications and Technology

IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE

StorWeek 7-15-09

Stored vs. Delivered Energy:

- 2.5% U.S
- 10% Europe
- 15% Japan

Which Country has most Outages?

Storage Types Examples

Laptop Computer	Power Grid

- **RAM**
  - Millions of operations/min
- **Hard Drive**
  - Current work
- **DVD & external drives**
  - Occasional Usage

- **Flywheels, Capacitors**
  - > 10^5 deep 15 min cycles
- **Batteries**
  - < than 10^4 deep 2-6 hour cycles
- **CAES and Pumped Hydro**
  - >1 day cycles


Flywheels


Batteries


Pumped hydro

- Technologies can do other functions – but not well!
- **Hybrid solutions may be most effective**
- **Each have different cost and pricing characteristics**

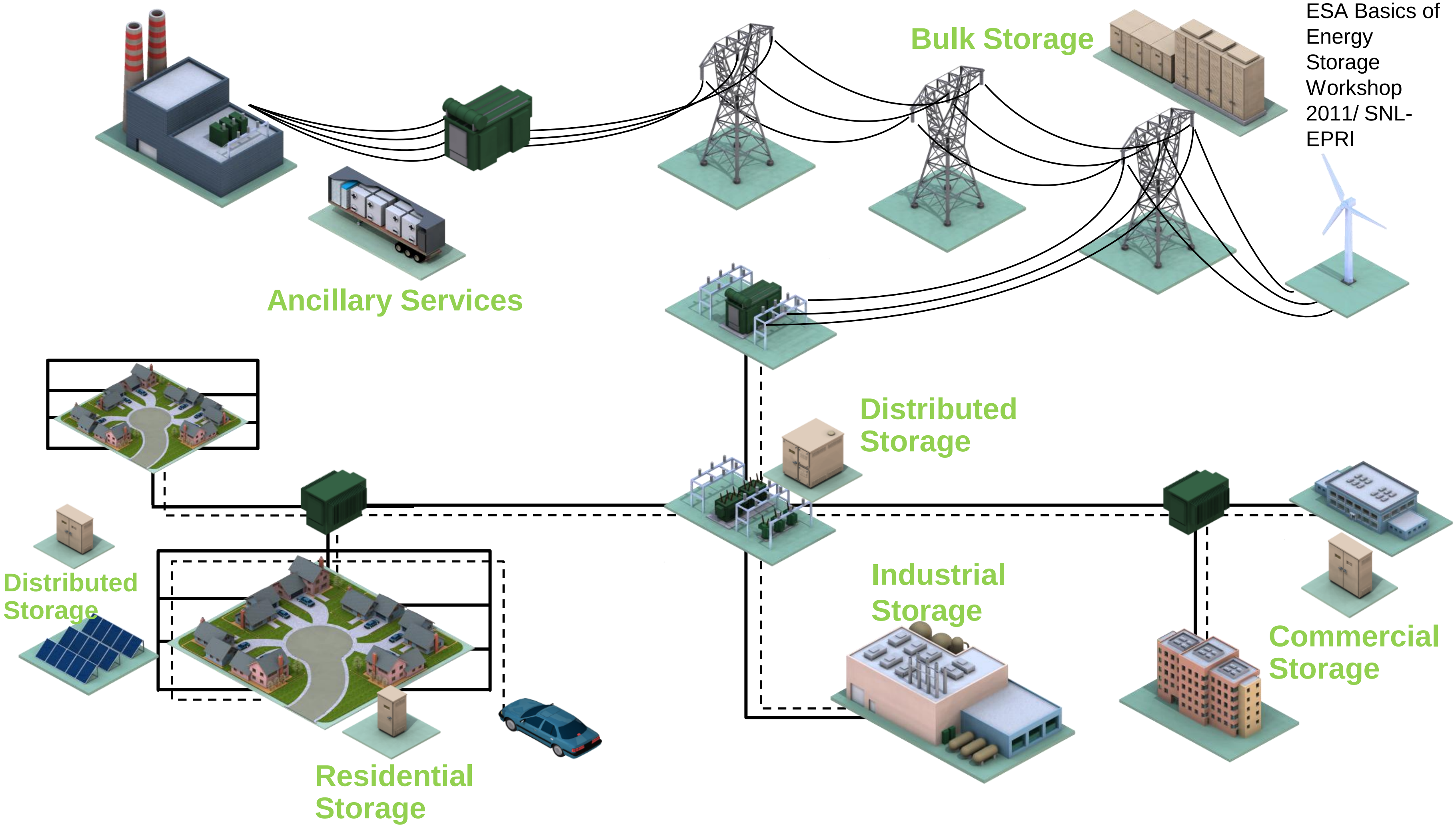
Introduction to Electrical Energy Storage (ES)

- **Energy Storage allows for the delivery of electricity when it is needed**
  - Decouples generation from Demand
- **Energy Storage Applications**
  - Two Main Applications are Power (<15 min) and Energy (>1hr)
    - Spinning Reserve - takes the place of generators performing load following
    - Transmission and distribution stabilization – Frequency regulation, Upgrade deferral, Transmission reliability
    - Renewable integration – allows variable energy sources to maintain constant output
    - End use application – demand reduction, time of use cost reduction power quality, system flexibility

Energy Storage Applications

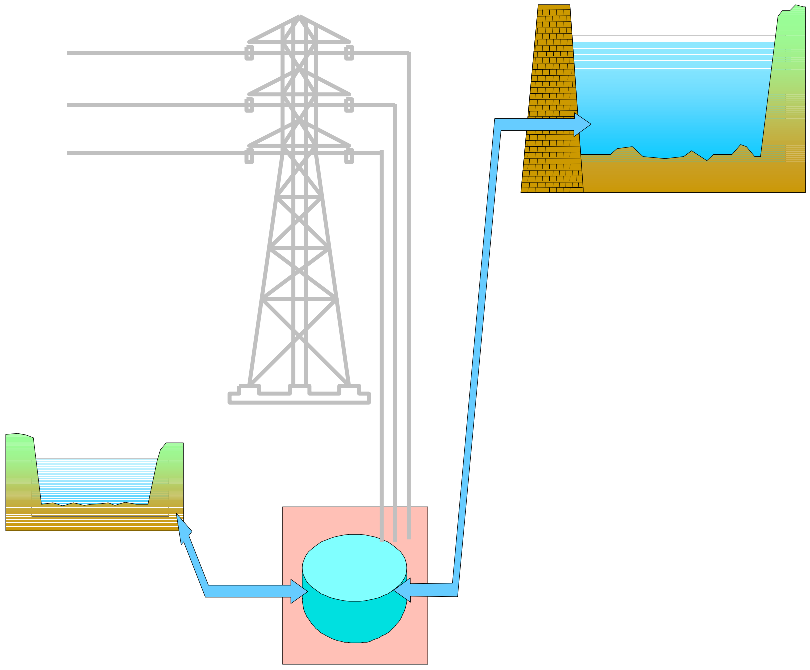
	POWER		ENERGY
LOAD	PQ, Digital Reliability	Load Following, UPS	Peak Shaving, Load Shifting
GRID	Voltage Support, Transients, Regulation	Dispatchability for Renewables	Congestion Mitigation, Arbitrage
	seconds	minutes	hours

Role Electrical Energy Storage On the Grid



ESA Basics of Energy Storage Workshop 2011/ SNL-EPRI

Pumped Hydro



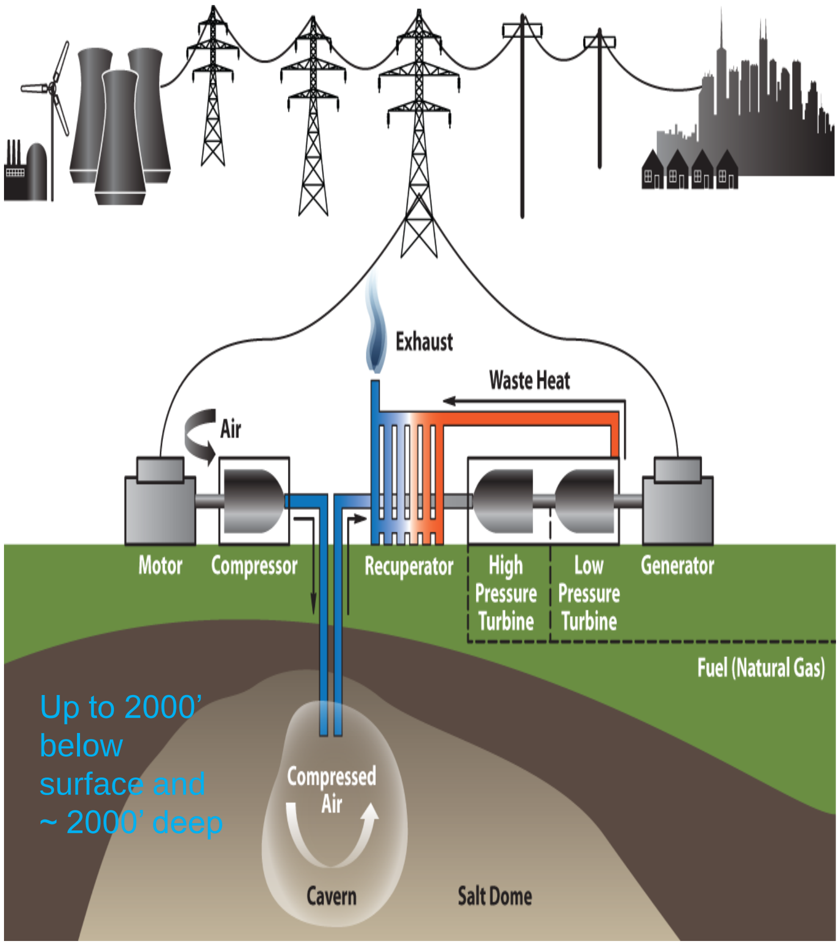
Water is pumped from one elevation to another and released through turbines to produce electricity. (Greatest percentage of installed Energy Storage capacity)

•High Energy and Power
• Fast response to load
•Low energy density
•Requires an Large body of water – permitting problematic
•Low cost to operate but, expensive to build

Grid Applications:
Energy (>1hr)

- Peak Shaving
- Demand reduction
- Energy Shifting

Compressed Air Energy Storage (CAES)



•Air is compressed and stored underground. Compressed air is used to generate electricity.

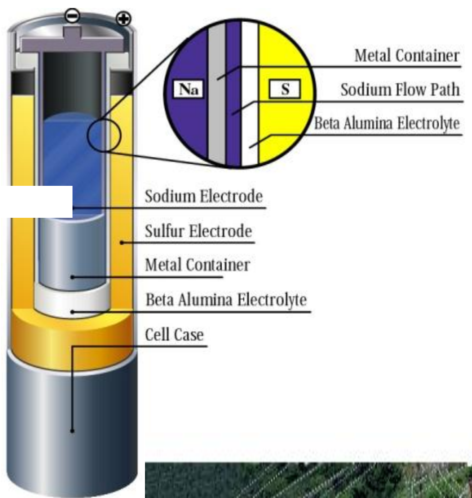
•High Energy and Power
• Fast response to load
•Low energy density
•Hard to site due to cavern requirements
•permitting problematic
•Low cost to operate but, expensive to build

Grid Applications:
Energy (>1hr)
- Peak Shaving
- Demand reduction
- Energy Shifting

Innovative Technologies

- Batteries transform chemical energy into electric energy
  - Sodium sulfur
  - Flow
  - Lead Acid
  - Li-ion
  - Aqueous Sodium
  - Iron Chromium
- Flywheels
- Capacitors
- Thermal
  - Molten Salt
  - Ice
- Site anywhere CAES

Sodium–Sulfur Battery (NaS)



molten-metal battery constructed from sodium (Na) and sulfur (S). such cells are primarily suitable for large-scale non-mobile applications such as grid energy storage.

Started Operation on June 26th, 2006

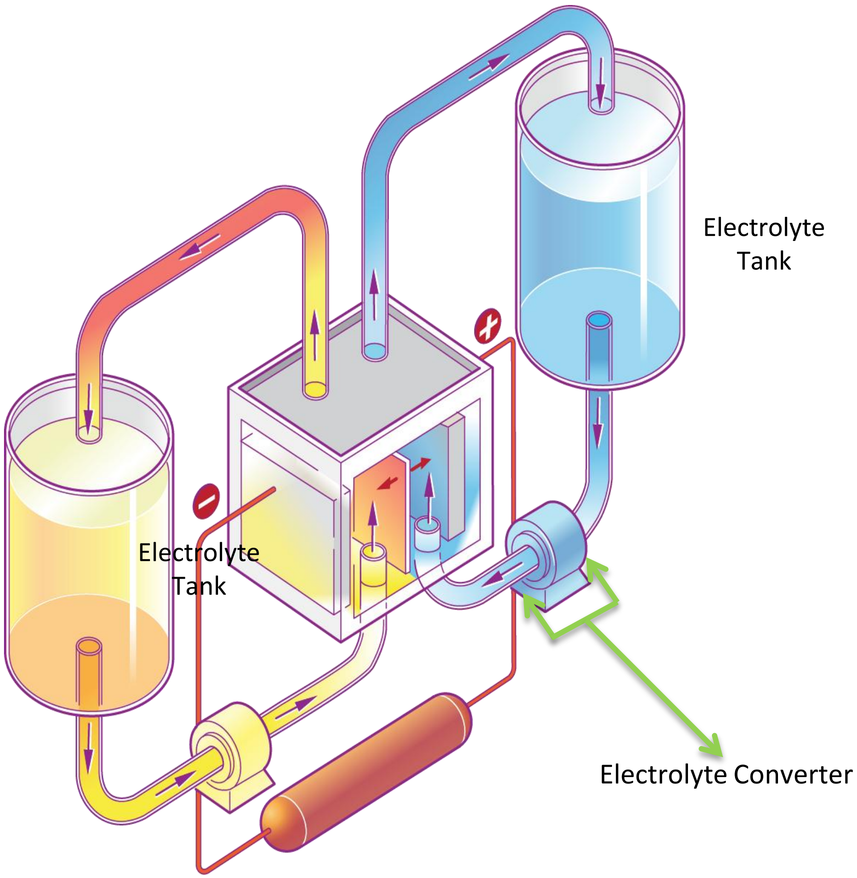
AEP APPALACHIAN POWER
A unit of American Electric Power

NGK Insulators Ltd
S&C Electric Co.
DOE / SANDIA

- High energy density
- High efficiency (89-92%)
- Long cycle life
- Thermal management issues
- High operating temps (300-350 °C)

Grid Applications:
Energy (>1 hr)
- Energy shifting
- Demand reduction
- Renewable support

Flow Batteries



Fuel cell in which electrolyte containing one or more dissolved electroactive species flows through a cell that reversibly converts chemical energy to electricity. Types include Zinc Bromine, Vanadium Redox

- Low density
- High complexity

Grid Applications:
Energy (>1 hr)

- Integration of renewables
- Off-Grid power system support
- Stand-by generator replacement

Lead Acid Batteries

Oldest and most common distributed energy resource device due to:

- Low cost
- Easy to integrate
- Mature industry with many applications

Grid Applications:

Power (<15 min) and Energy (>1 hr)

•UPS, Demand reduction, renewable integration

Critical Load Backup/ Energy Management
Lead Smelter: Battery Recycling
5 MW, 3.5 MWH VRLA Battery

Advanced Lead Carbon

Evolving technology for lead-acid batteries uses Carbon in the battery which allows for increased cycles:

- <1000 for traditional, >4000 for Lead Carbon

Grid Applications:

Primarily a power (<15 min) battery but testing being done to utilize in energy (>1hr) applications

- Renewable integration, Frequency Regulation

Lithium Ion

Developed for electric vehicles, and now being utilized for grid storage applications.
- High energy density per unit weight.
- High cycle life

Applications:
Presently used in power applications (<15 min).
Demonstrations in development to utilize Li-ion in energy applications (>1Hr)
- Utilized as an alternative to generators used to provide frequency regulation on the grid.

Flywheels

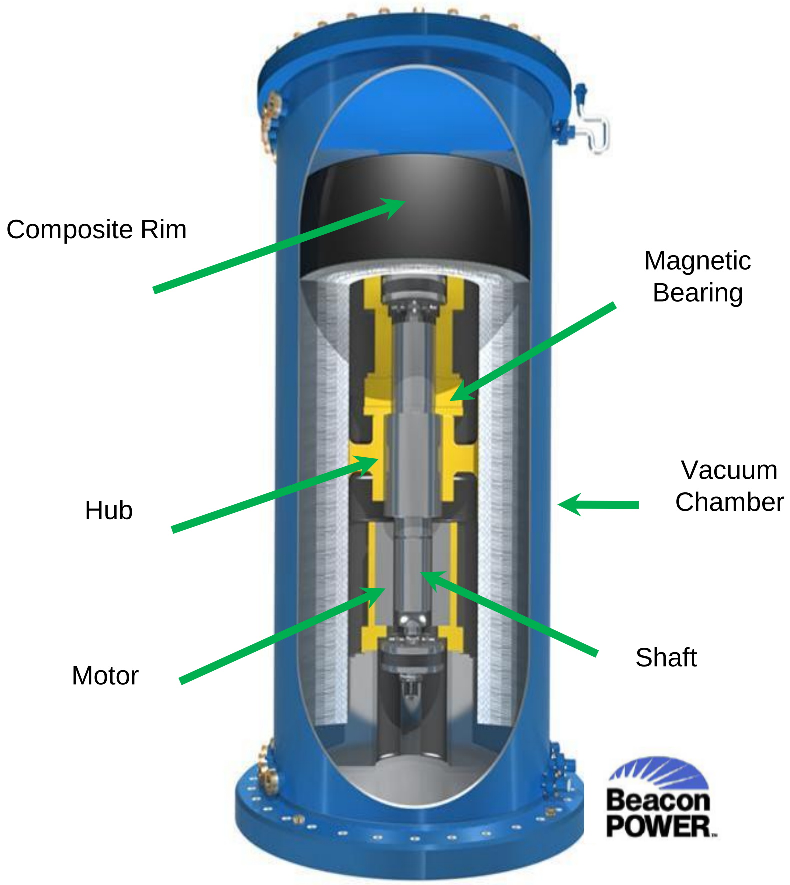
A rotating cylinder's momentum stores energy

- **High power density and cycle life**
- **Recharge quickly**
- **Low energy density**

Applications:

Power Applications (<15 min)

- **Utilized as an alternative to generators to provide frequency regulation on the grid.**



Electrochemical Capacitors
(supercapacitors, ultracapacitors)

Stores energy through separation of electrical charge (electrical double layer)

- High power density
- Longer cycle life than most batteries
- Low energy density

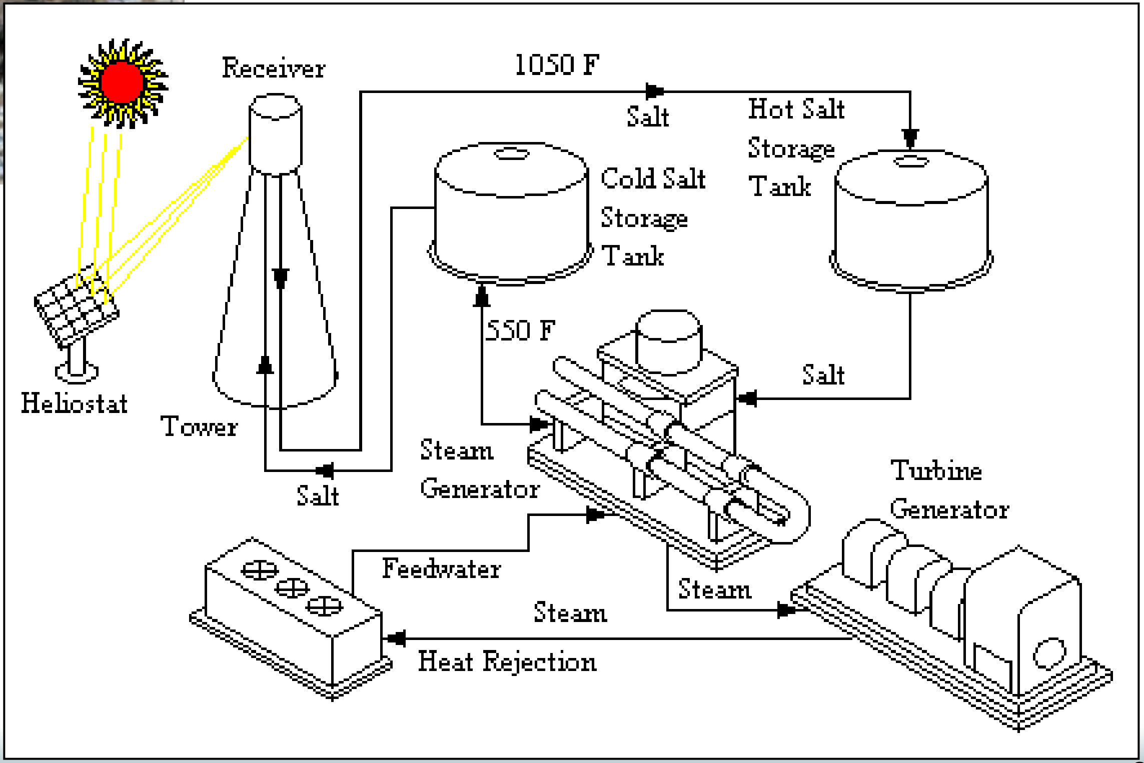
Applications:

Power applications (<15min)

- Power Quality – UPS, Power factor
- Renewable voltage regulation

Solar Thermal Generation w/Storage

- Concentrated sunlight heats thermal salt to over 1000 degrees F
- Thermal salt used to create steam
- Steam drives traditional turbine generator



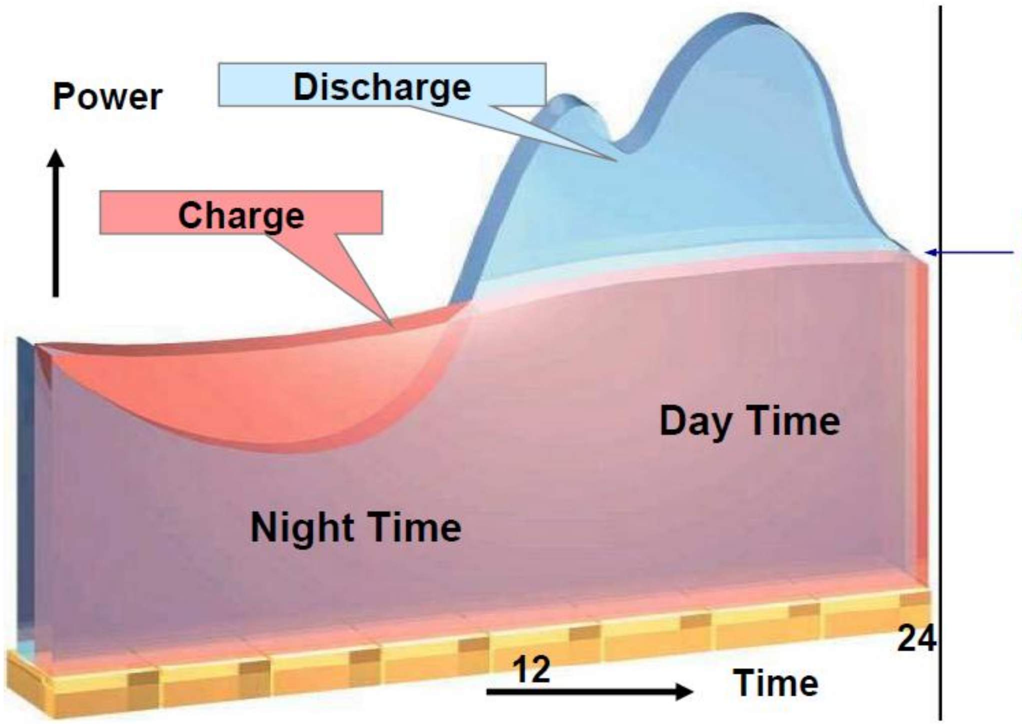
- Does not "charge" and "discharge"
- Provides "dispatchability"
- Challenging maintenance issues

Ice Storage

Ice Bear Units at a Community College

- System makes ice at night
- Uses ice for A/C during day
- Avoids the need for electricity for A/C during the day

Storage Applications – Load Leveling

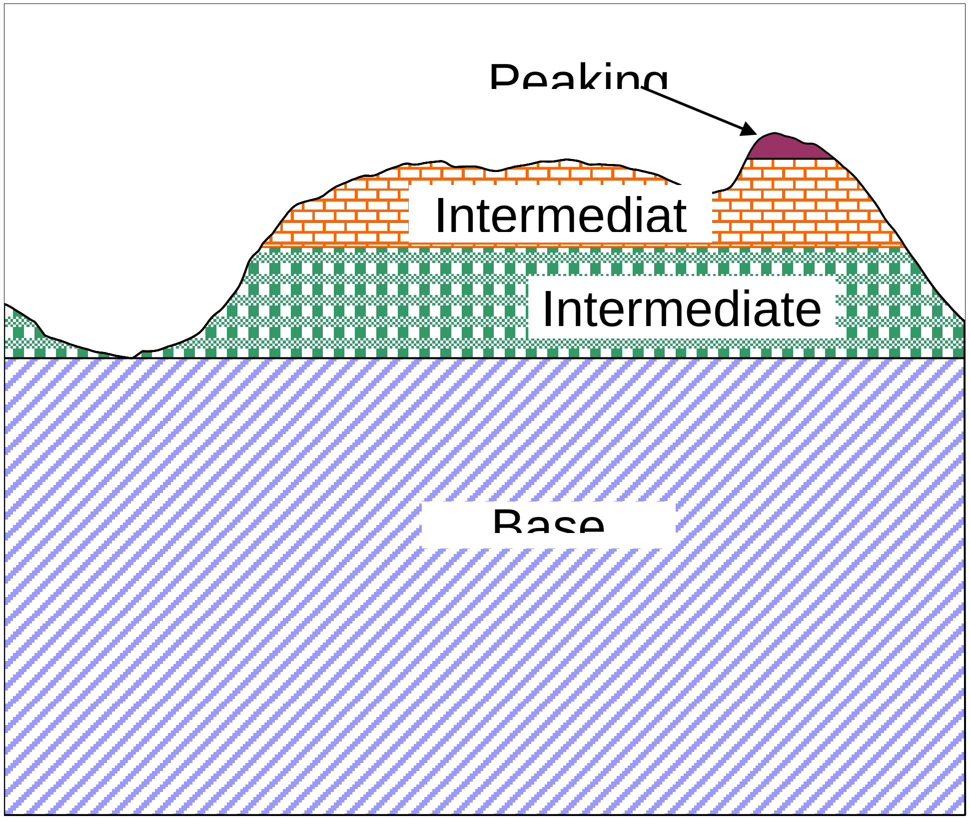


Ameren: Taum Sauk, Missouri,
440MW re-commissioned May, 2010

Arbitrage has difficult economics today

Storage Applications – Peak Shaving

MW



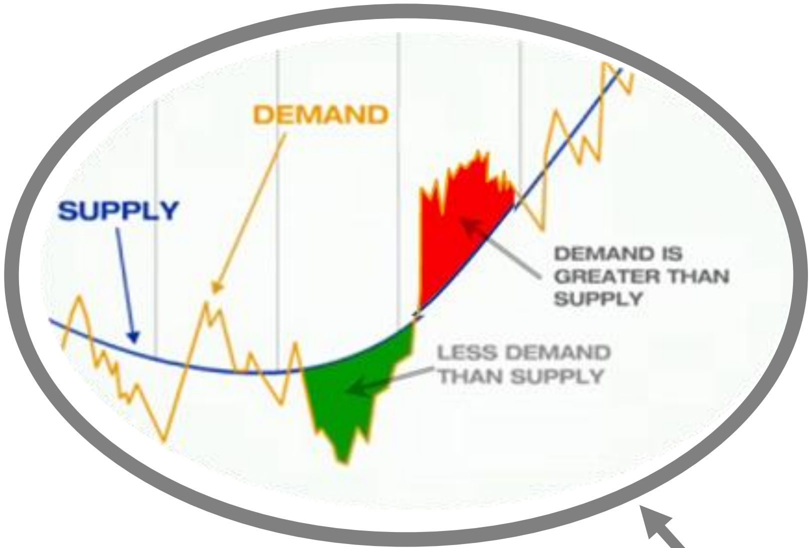
Storage could reduce or eliminate use of low efficiency peaking units

NaS battery

34 MW, 7 Hour Battery with 51 MW Windfarm

Source: Energy Storage Association – www.energystorage.org

Storage Applications – Frequency Regulation



- Short duration **Ancillary Service** to help balance grid.
- Typically < 15 minutes
- Short duration, highly cyclic mission

- ~1% of forecast load
- **up to ~3% needed for renewables**

Storage fast response and new FERC Order 755 = good economics

Storage is Becoming Practical For Minute-to-Minute Regulation

20 MW flywheel system operating in NYISO

8 MW Li-ion battery system in NYISO

Renewables Need more Regulation

Expected increase in Regulation capacity (MW) requirements at 20% and 33% RPS (Spring*)

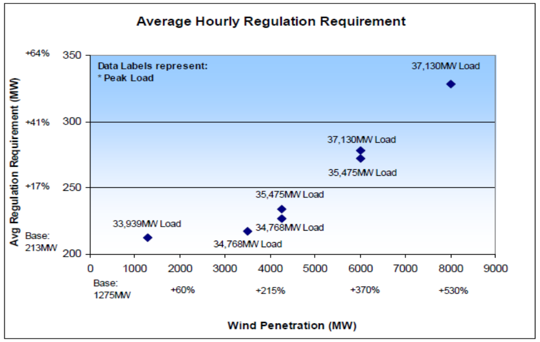
	2006	2012	2020
Maximum Regulation Up Requirement (MW)	277	502	1,135
Maximum Regulation Down Requirement (MW)	-382	-569	-1,097

California ISO

Requirement increases by 300% with 33% wind

Regulation Req. vs. Wind Level

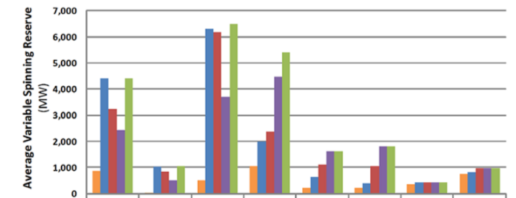
- As shown in the graph below, the average regulation requirement increases approximately 9% for every 1,000MW increase between the 4,250MW and 8,000MW wind penetration level.



Requirement increases by 60% with 10% wind

Impact of 20% Wind Penetration in Eastern U.S.

Beacon POWER



	MISO	MAPP	SPP	PJM	NYISO	ISO-NE	TVA	SERC
Load Only	885	43	514	1055	217	202	365	741
Actual Wind S1	4,424	1,020	6,308	1,994	618	399	420	816
Actual Wind S2	3,245	835	6,176	2,359	1,118	1,046	418	955
Actual Wind S3	2,419	503	3,695	4,463	1,614	1,789	418	955
Actual Wind S4	4,423	1,038	6,487	5,410	1,614	1,789	418	955

Region

"Load Only" is today's regulation requirement

Scenarios 1,2,3 show different mixes of on-shore, off-shore and regional mixes for 20% wind penetration

Scenario 4 is 30% wind penetration

*For 20% wind penetration, the **average increase** in forecasted need for regulation resources is **several hundred percent**…*

EASTERN WIND INTEGRATION AND TRANSMISSION STUDY, January 2010 Prepared for NREL by: EnerNex Corporation Knoxville, Tennessee, NREL Technical Monitor: David Corbus, Prepared under Subcontract No. AAM-8-88513-01

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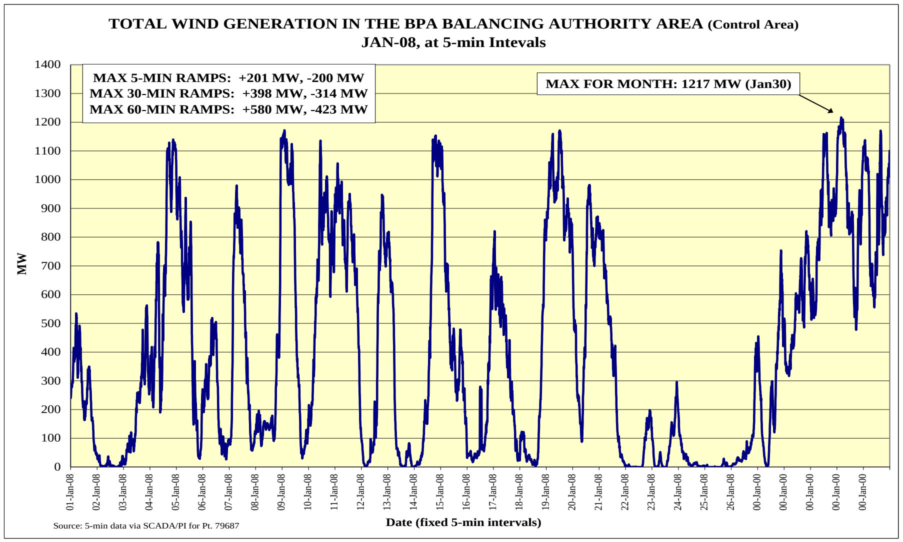
"PJM expects the requirement for regulation to increase from 1,000 MW today to 2,000 MW when we reach 20% wind penetration."

– Terry Boston, CEO of PJM
Storage Week conference, July 13, 2010

Requirement increases by 200% with 20% wind

Variable Energy Resources Create More Demand for Balancing

Wind

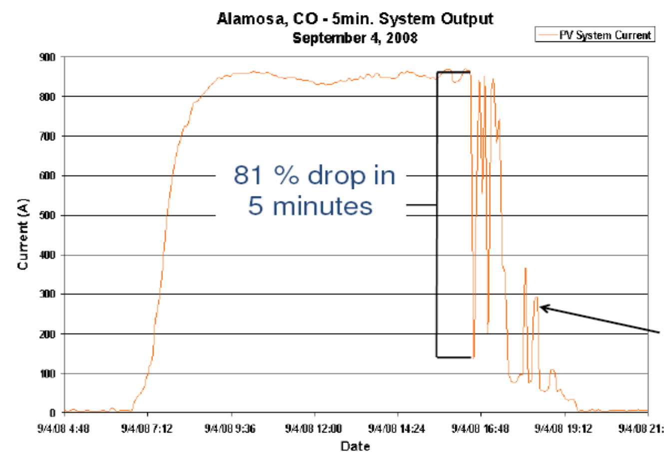


Bonneville Power 1 month wind data

- Power range >1200 MW
- Fluctuations in both 5 minute and 6 hour time frames

Solar

Solar energy sources are highly variable



Output from an 8MW solar PV panel in Colorado on 9/4/08

High variability due to clouds

Typical daily solar power pattern

- Fluctuations can be >80% rated power in 5 minutes
- Can continuously fluctuate on partially cloudy days

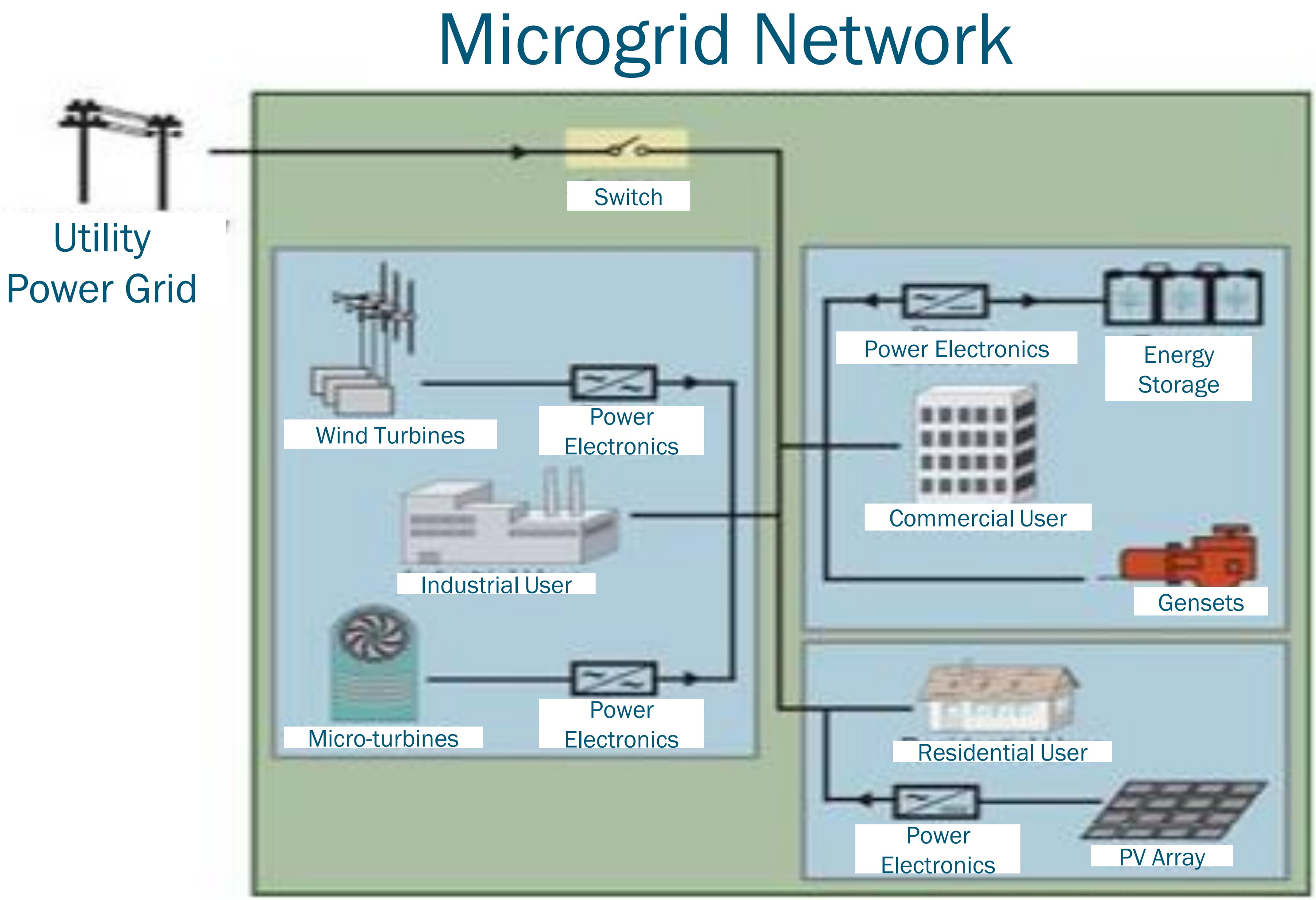
Renewables need all three time scales of storage

Where are the Opportunities? (10+ MW scale)

- **Long duration storage** (Civil Engineering Projects)
  - Pumped hydro installations
  - Compressed air installations (i.e. salt caverns)
  - New dams
- **Peak Shaving** (2-6 hours)
  - Batteries of every kind (Inverter-based installations)
  - Pipe storage based Compressed Air
- **Frequency Regulation and Response** (<15 min)
  - Flywheels
  - Advanced batteries?

Frequency Regulation has best economic short term value

Microgrid Applications – i.e. Disconnected Distribution Line



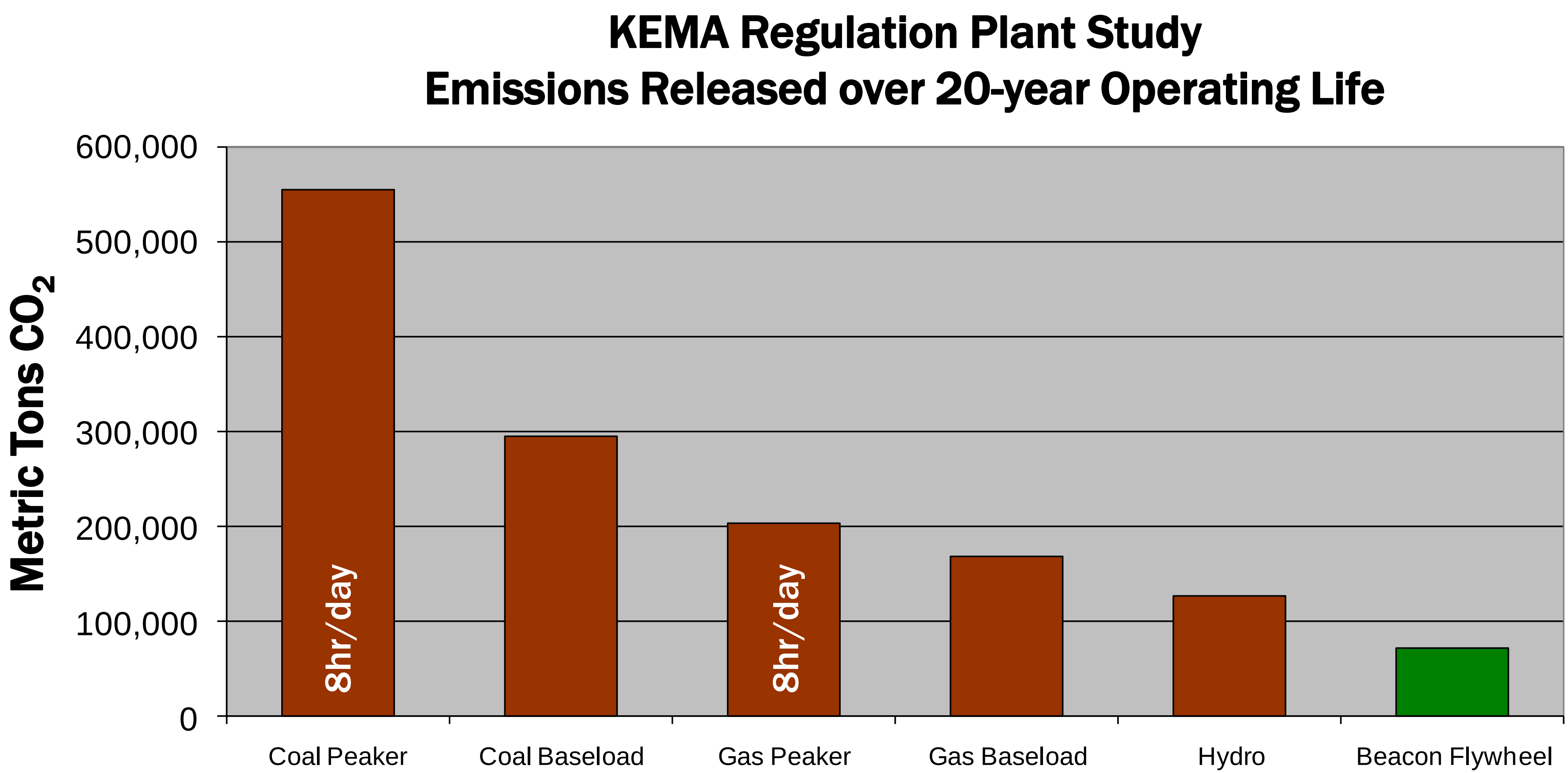
Microgrid Stability

Stability depends on Load/Power balance

- Load = Generation to maintain 60 Hz on system
  - Load changes Quickly – at flick of a switch
  - Generator do not load follow instantly
    - Diesels are fastest load followers
- Renewables are intermittent and variable
  - Cannot be relied upon by themselves to follow load

- **Traditionally diesels provide fastest response**
- **Storage is faster and may be a better choice**

Dramatically Lower CO_2 Emissions



Significant reduction in CO_2 emissions vs. present methods

Think Hybrid!

- **Today's paradigm: Traditional architecture**
  - Diesels are fastest gen choice for Microgrids
- **Tomorrow's reality: Storage - Generator hybrid**
  - Works same way as hybrid vehicles
  - Generator will cycle less – better efficiency
  - Generator can be more efficient design slower
- **Better efficiency = lower fuel consumption emissions**
- **Less generator cycling = longer life**

Lessons Learned: 2003 NE Blackout Islanding issues?

- Many generators selected for high efficiency
  - Depended on grid for load following
  - Depended on grid for voltage support
  - Both disappeared when grid went down
  - Generators forced to shut down
- Storage could have provided both
  - Higher efficiency generators could have been used with storage Reduced consumption fuel could have offset some cost

Adequate voltage support (VARs) and load following must be provided inside the microgrid

Is Storage Expensive?

$/kW?

$/kWh?

What is in the “$”

Acquisition Cost?
Total System Cost
Life Cycle Cost?
Installation Cost?
Disposal Cost?
Maintenance Cost?

What is in the “kW”or“kWh”?

At rated conditions?
Exclude system losses?
Delivered amount?
Available for delivery?
Total stored?
Amount per cycle?

- **Cost metric must include all important elements**
- **Use project ROI for decision**

Summary

- Storage is everywhere, why does US power grid have so little?
- Storage delivers power when needed just as Transmission delivers where needed (Dr. Imre Gyuk)
- Think of storage like memory on a computer
  - One size does not fit all
  - Several different types are needed
  - Use the right tool for the job

Summary

- Think of grid storage like a batteries on a hybrid car
  - Better fuel usage, less emissions
- Microgrids benefit from storage for stability
- Use project ROI or IRR instead of $/kW and $/kWh as a cost metric
- Storage should be treated like a renewable resource

Resources

- www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/
- www.electricitystorage.org
- http://energy.gov/oe/services/electricity-advisory-committee-eac

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Or visit *http://www.ct.gov/deep/cwp/view.asp?a=4120&Q=508780*