INTEGRATION OF RENEWABLE INTO THE GRID
Role of Energy Storage

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Presentation Overview

- Impact of Renewables on Grid Operation
- Value of Energy Storage
  - Storage Technologies
  - Bulk vs. Distributed Storage
- Impact of Federal Stimulus Programs
- Storage Role in Smart Grid
- The Influence of Electric Transportation

Impact of Renewables on Grid Operation

- Growth of wind resources remote from load centers
  - Mismatch between load and source peaks
  - Transmission constraints
- Large amounts of rooftop solar will start to impact distribution voltage control
- Achieving RPS standards will create need for more ancillary services and balancing energy sources to insure reliable performance of grid
- Optimizing bulk-power production is becoming much more difficult

What Will be the Most Transformative Technology for the Electricity Industry?

1. **Renewables and low-carbon generation tech.**
2. **Transmission superhighways**
3. **Energy storage technologies, inc. PHEVs**
4. **An integrated Smart Grid**
5. **Demand resources that reduce newbuilds**

What Will be the Most Transformative Technology for the Electricity Industry?

15%	1. Renewables and low-carbon generation tech.
19%	2. Transmission superhighways
38%	3. Energy storage technologies, inc. PHEVs
26%	4. An integrated Smart Grid
3%	5. Demand resources that reduce newbuilds

Value of Energy Storage

- Pumped hydro power has played a valuable role in grid operations
- Role of storage in the future grid is receiving more attention
- Storage will be a facilitator of Smart Grid deployment
- A “small amount” of storage will have a ‘large impact” on the future grid

Energy Storage Alternatives

- Pumped hydro
  - Typically greater than 200 MW and days of storage
- Compressed Air Energy Storage (CAES)
  - 50 - 500 MW based on blended gas/air generation
- Distributed Energy Storage System (DESS)

  -High temperature batteries up to 50 MW

  -Flywheels/lithium-ion up to 20 MW
- Community Energy Storage (CES)

  - 25 – 50 kW, 1 – 2 hour pad-mounted

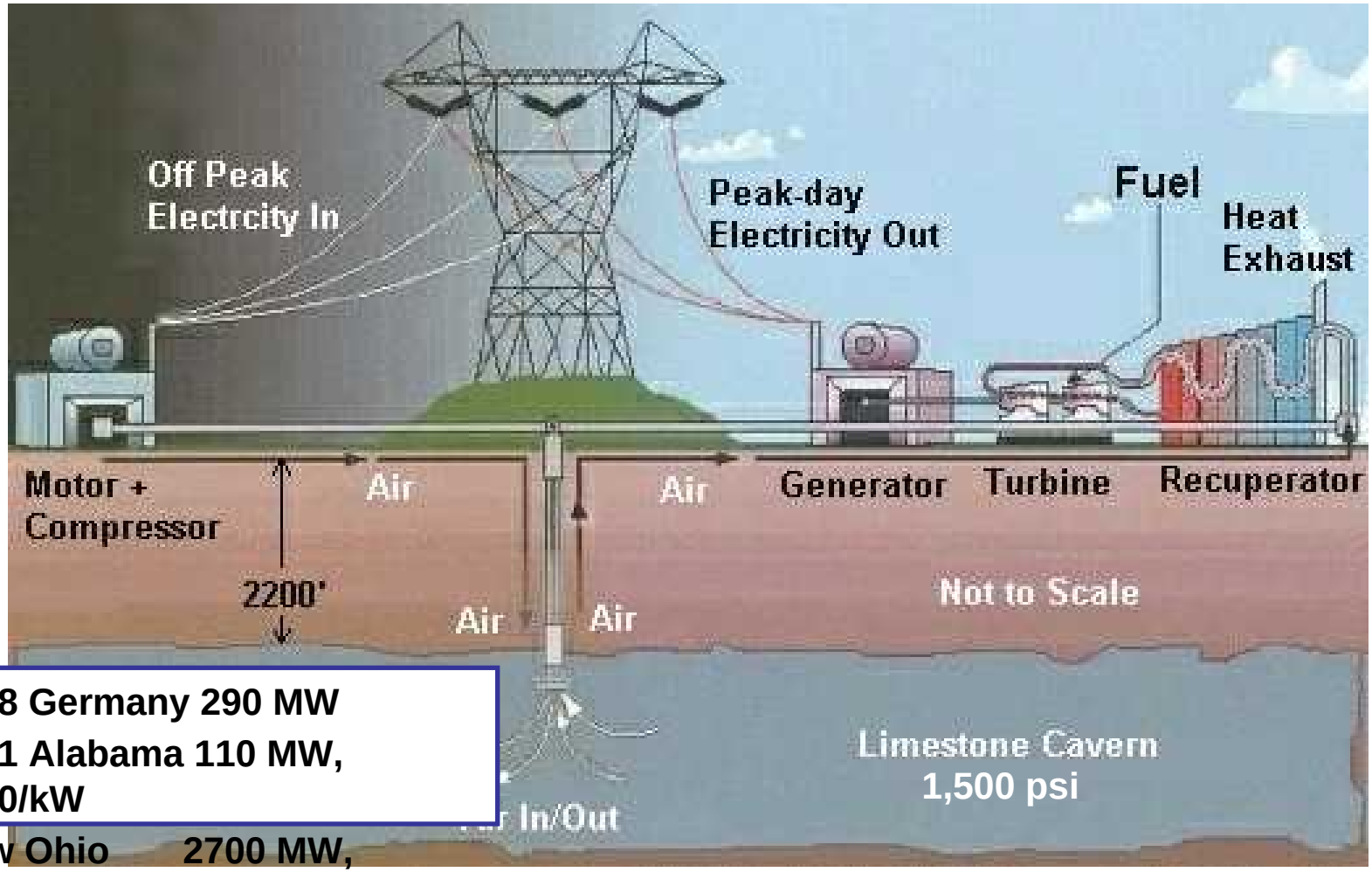
Storage in the Grid Today

	US (MWs)	Globally (MWs)
Pumped Hydro	22,000	88,000
CAES	110	367
NAS	8	250
NiCad	26	0
Other	10	10
Totals	22,154	88,627

Pumped Hydro Storage

Compressed Air Energy Storage
115MW, 26 Hour System

Compressed Air Energy Storage

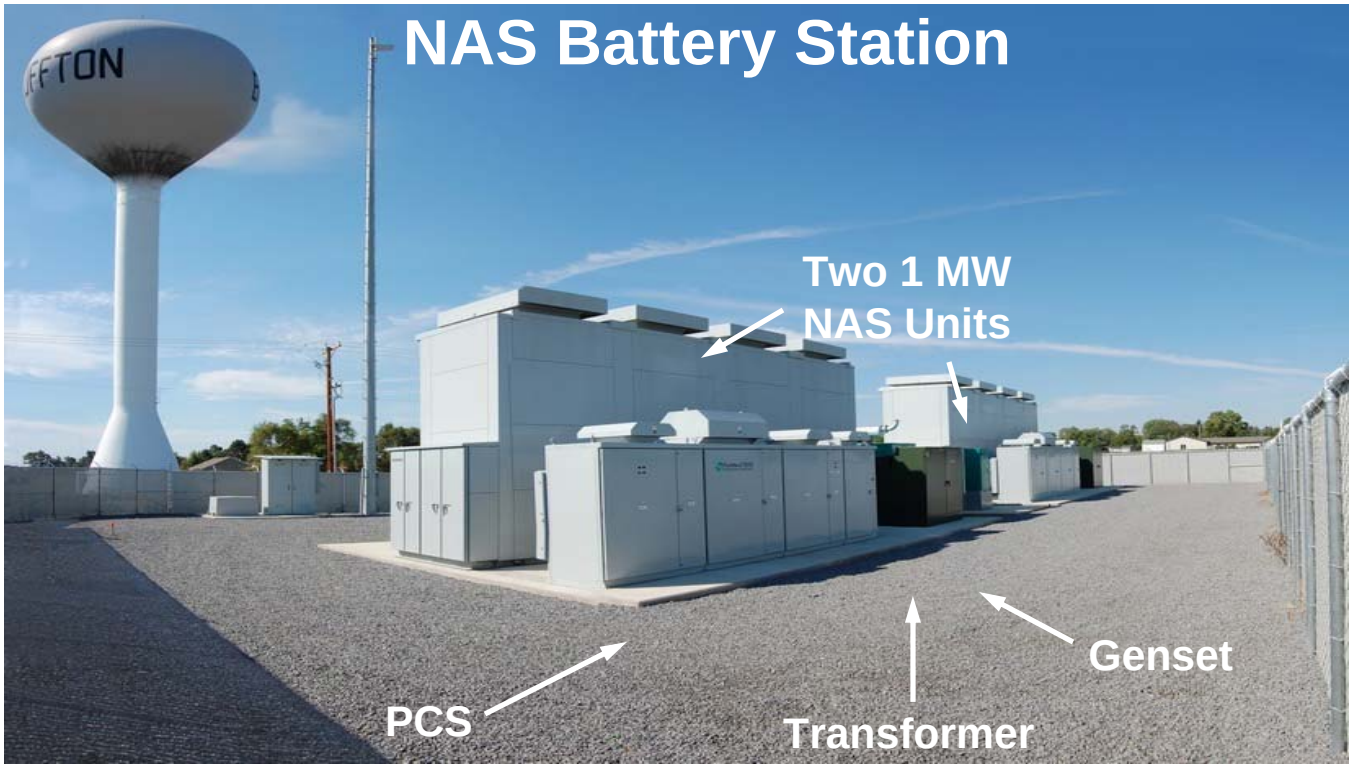


- 1978 Germany 290 MW
- 1991 Alabama 110 MW, $590/kW
- Now Ohio 2700 MW, $370/kW

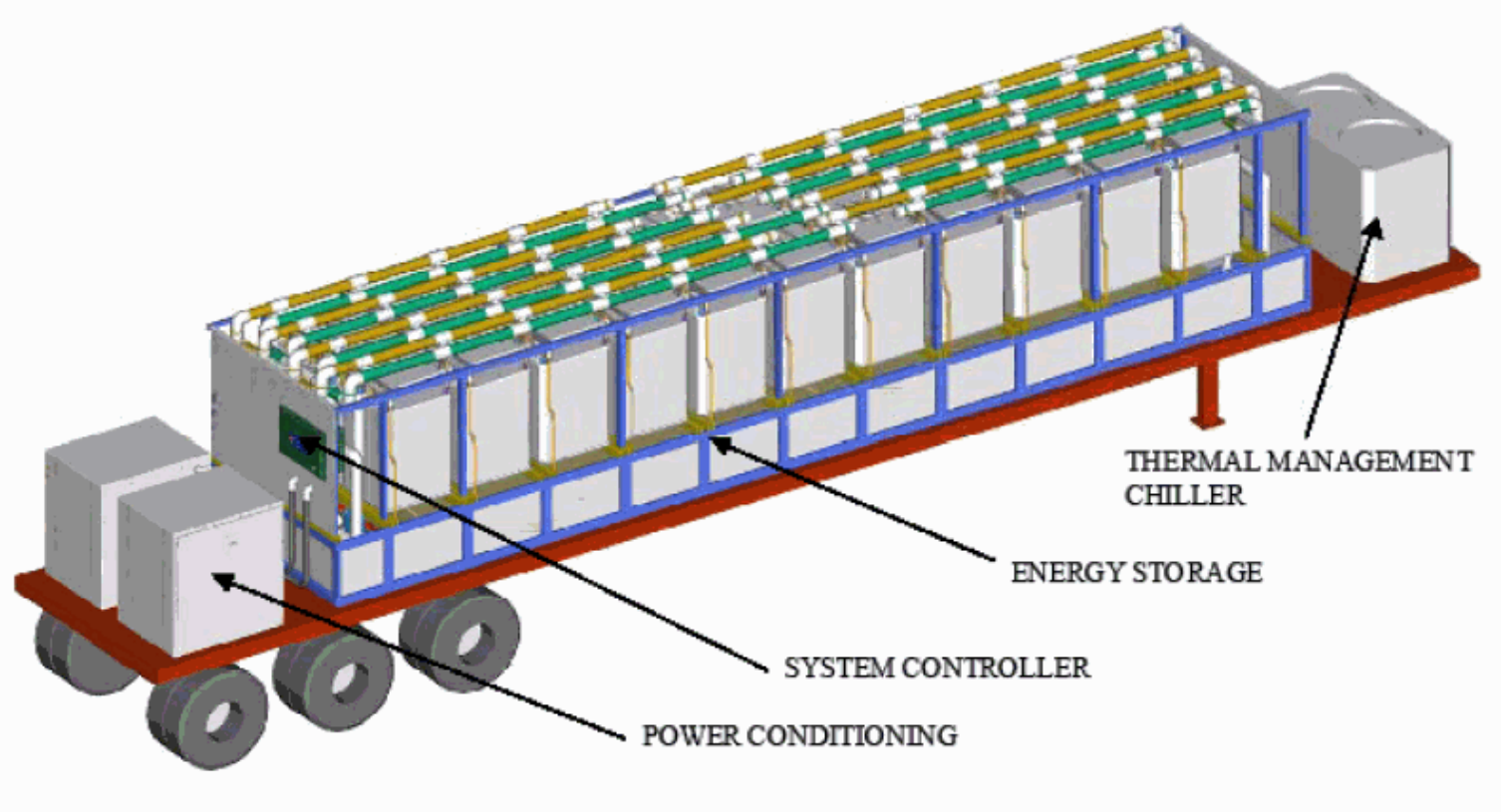
High Capacity - Low Cost - Special Site Requirement -Gas Fuel –Slow Response

Distributed Energy Storage

- 2 MW, 14.4 MWh in Bluffton, Ohio
- Two other identical sites in West Virginia and Indiana (2008)
- All with dynamic islanding

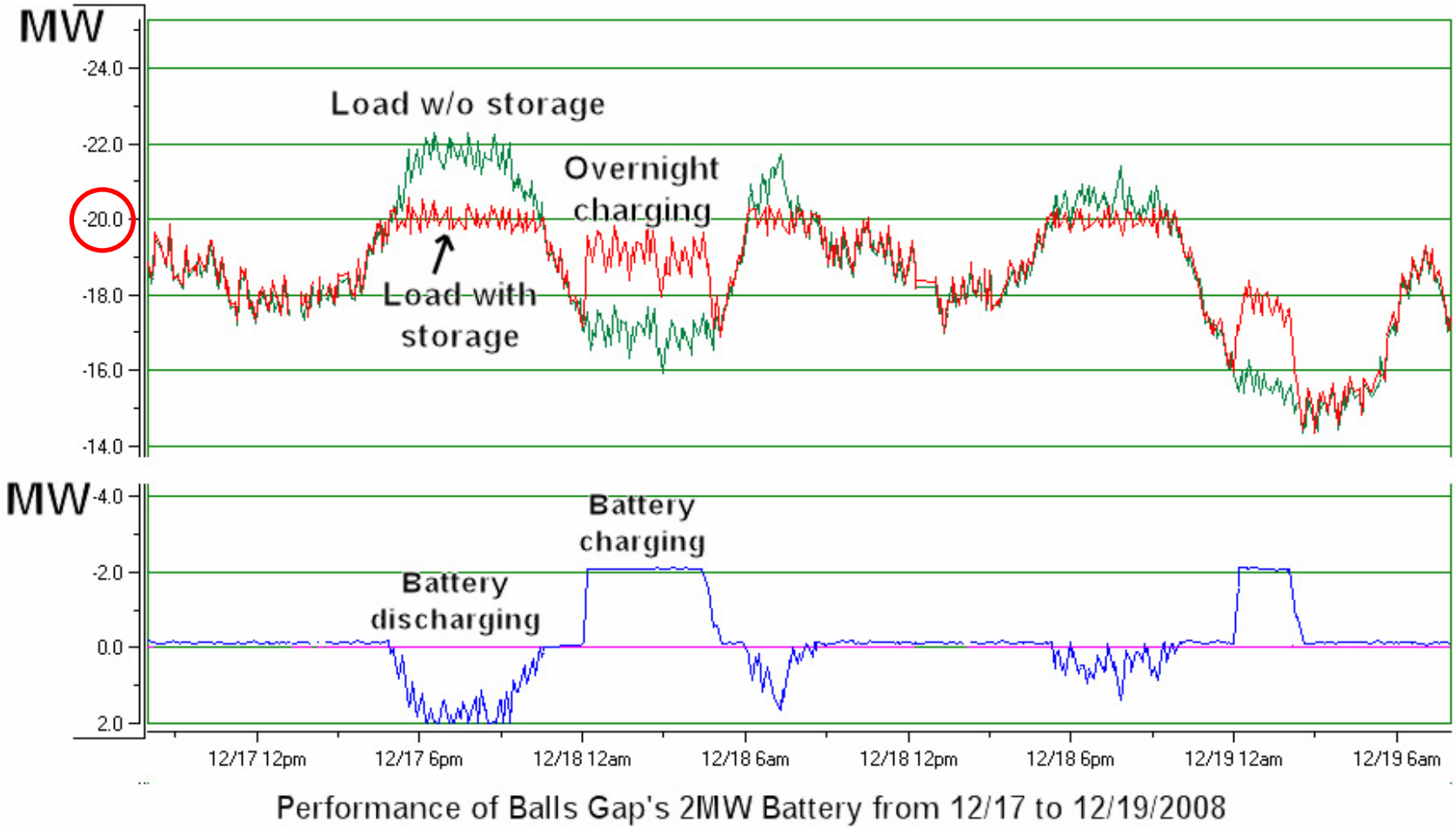


Distributed Energy Storage
Zinc Flow Battery



Distributed Energy Storage

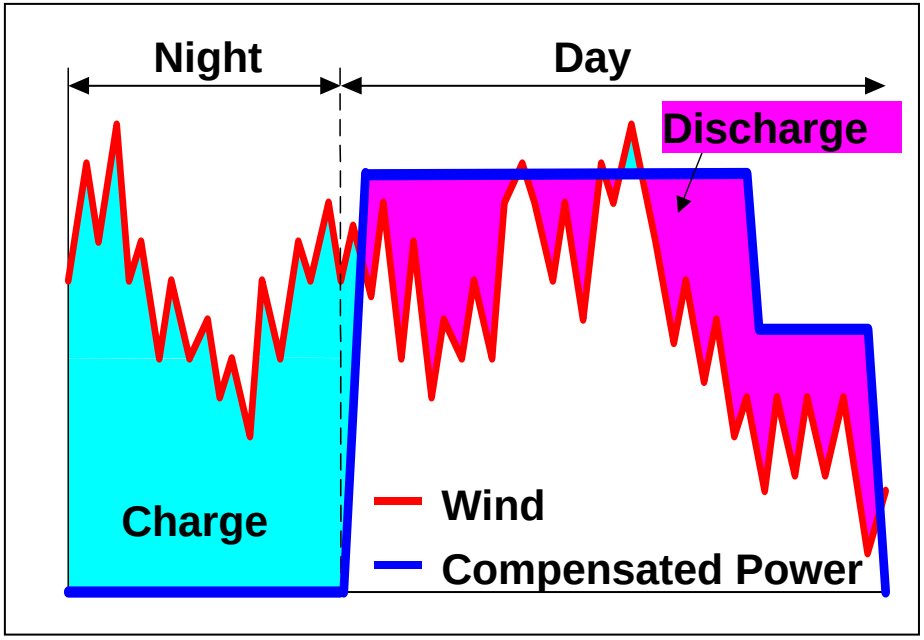
- Load Following (peak shaving)

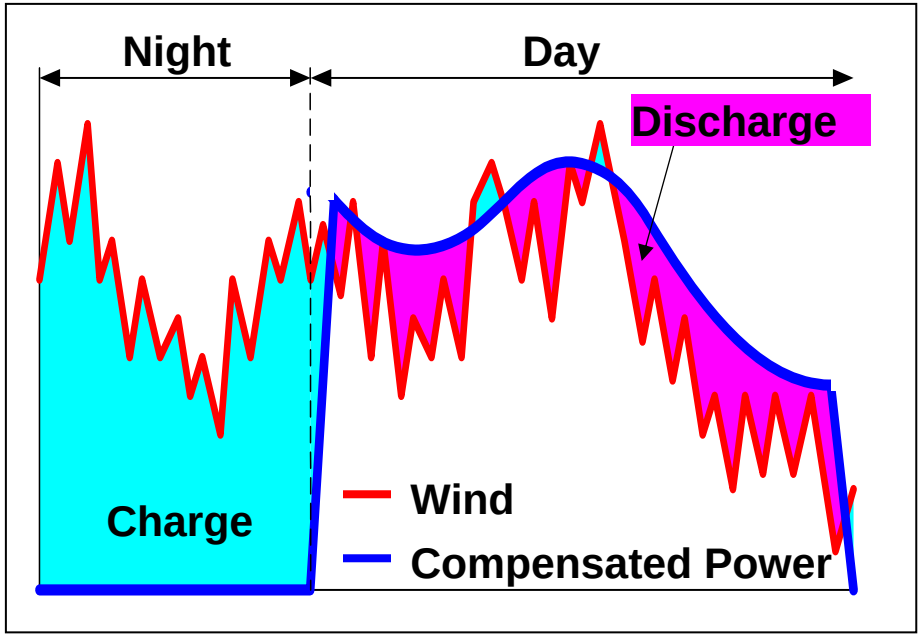


Performance of Balls Gap's 2MW Battery from 12/17 to 12/19/2008

Distributed Energy Storage
34 MW, 7 Hour Battery with 51 MW Windfarm

Time Shifting and Dispatch of Renewable Energy





Wind farm output is stored (curtailed) if load-following reserves are not adequate.

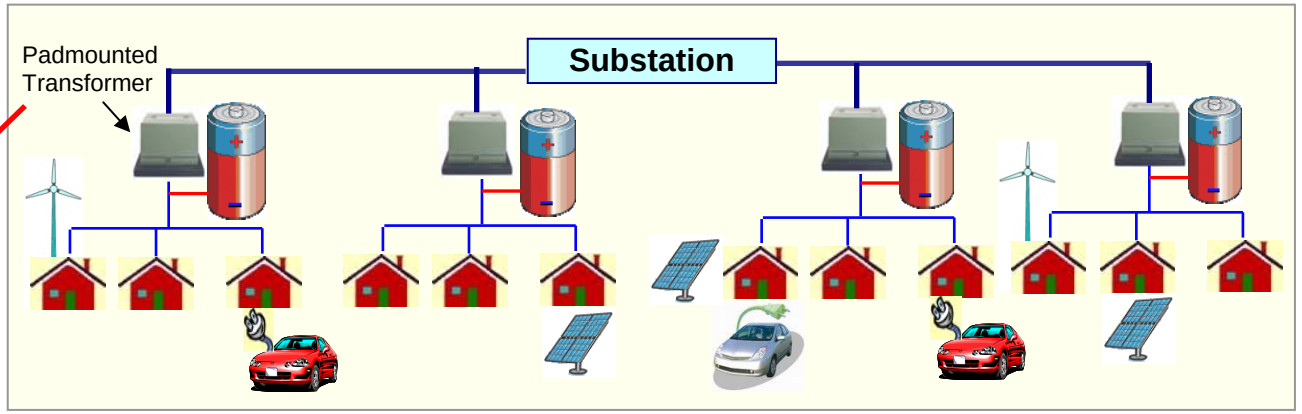
Flywheels (Kinetic Energy)

- Ancillary Service Application
  - 1.0Mw example (10 X 100Kw, 15 min.)

Lithium-Ion Battery
1.0MW, 15 min ancillary service

Community Energy Storage

- Improved service reliability and efficiency (close to customers)
- Voltage sag mitigation and emergency transformer load relief
- Multi-MW, Multi-hour ***when aggregated,*** (leverage AMI[1])
- Potentially low cost (synergy with PHEV[2])

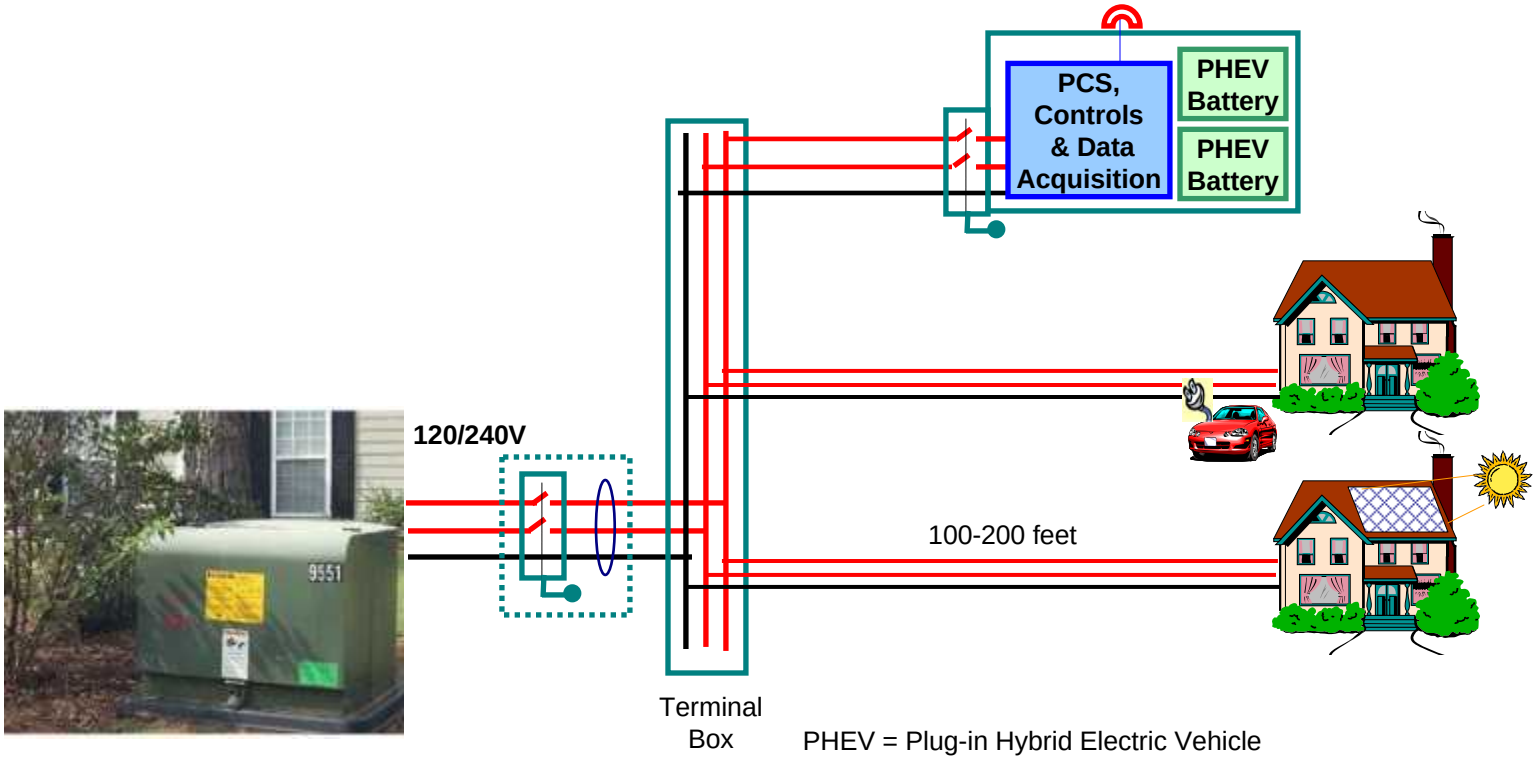


1- AMI = Advanced Metering Infrastructure

2- PHEV = Plug-in Hybrid Electric Vehicle

Community Energy Storage

- Leverages PHEV battery technology
- Serves as a substation battery when aggregated
  - Improved service reliability
  - Buffers PHEV & customer DG impacts



Impact of Federal Stimulus Programs

- Broad-based Incentive Packages
  - $2.4B for electric vehicles demonstrations and deployment projects for new US battery plants
  - $3.375B for Smart Grid Investment Grant Program
  - $615M for targeted demonstrations in Smart Grid, energy storage and grid monitoring (phasors)
- Will there be continued growth after stimulus is spent?

Impact of Federal Stimulus Programs

Area of Interest	Funding
Battery storage for utility load shifting or wind farm diurnal operations and ramping control	$40 – 50M
Frequency regulation ancillary services	$40 – 50M
Distributed energy storage for grid support	$25M
Compressed air energy storage	$50 - 60M
Demonstration of promising energy storage technologies	$25M

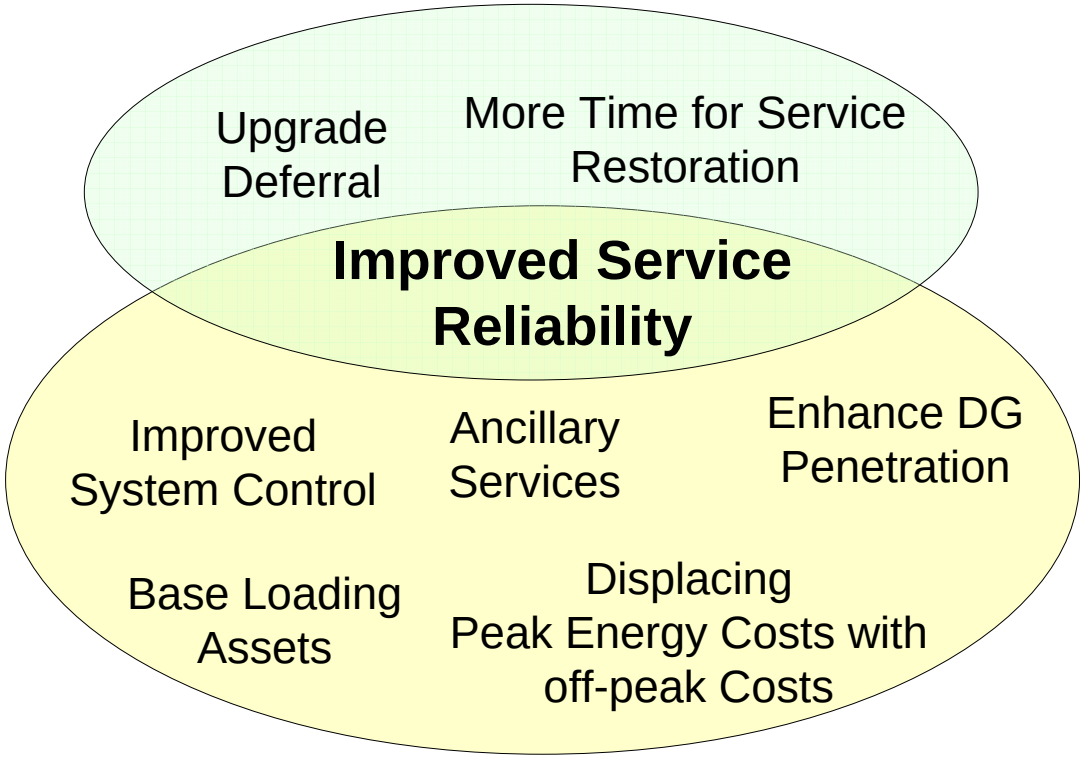
Storage Role in Smart Grid

- Storage is one of a set of new resources and technologies that will facilitate a smarter grid
- More bulk and distributed storage will help balance demand and bulk-power resources and dealing with transmission constraints
- Regulators need guidance in proper integration of storage value proposition
- The focus needs to remain on service reliability improvement

Time-View of Storage Benefits

Short -Term

Long -Term



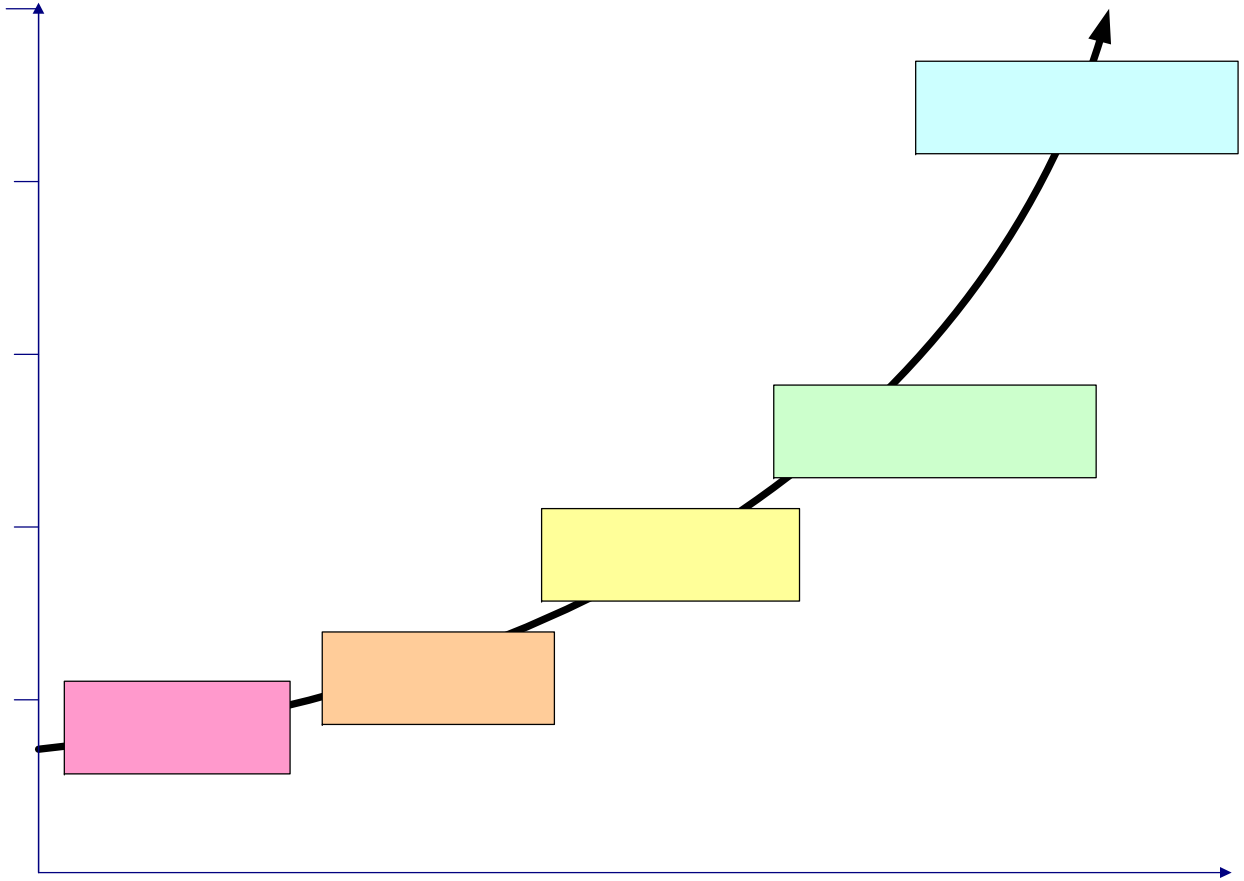
Improved Service Reliability is achievable in both Short-Term and Long-Term

Courtesy of AEP

The Influence of Electric Transportation

- Two huge industries (utility and automotive) are in the process of transformation
- Energy Storage is the problem and the solution for both
- Both will benefit from acceleration of battery technology

Exponential Improvement in Performance



The Influence of Electric Transportation

- Smart charging of PHEVs and EVs will be a key Smart Grid component
- Expanded battery production will dramatically lower costs for utility applications
- 30 million electric vehicles by 2030 will represent over 500 GWs of new load

For Further Reference

- Department of Energy, Electricity Advisory Committee
  - Keeping the Lights On
  - Smart Grid: Enabler of the New Energy Economy
  - Bottling Electricity: Storage as a Strategic Tool for Managing Variability and Capacity Concerns in the Modern Grid

  Reports available at: http://www.oe.energy.gov/eac.htm
- IEEE Power & Energy Magazine Volume 7, Number 4, July/August 2009 “Energy Storage Issue”

  Available at: www.ieee-pes.org