Energy Storage

The Sixth Dimension of the Electricity Production and Delivery Value Chain

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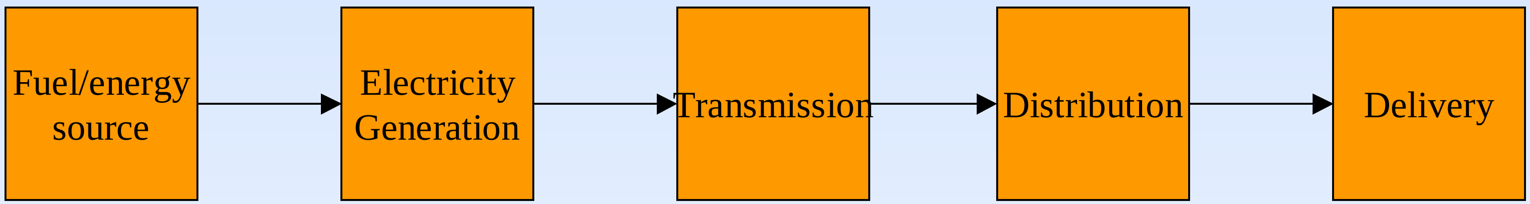
Our “Elevator Pitch”

- Energy storage has a critical role to play in our nation’s electricity infrastructure
  - Securing and assuring our critical assets
  - Raising the value of renewables to the market
  - Optimizing the productivity of fossil-fired generation
  - Facilitating the transition to regional transmission organizations and a nationally competitive electricity market
  - Supporting distributed generation (DG) by bridging the gap between uninterruptible power systems (UPS) and DG prime movers

Policy Implications of Energy Storage

- Storage must be recognized as the sixth dimension of the electricity value chain
- Security and reliability issues may suggest that a minimum storage capacity should be a federal government goal. *The infrastructure backbone…*
- R&D must be continued and expanded for small-scale storage. Advanced technologies for large-scale energy storage should be added to current programs
- Detailed system and economic modeling at three levels, with storage assets plugged in, is essential to quantify storage value buckets that currently are vague
  - Transmission- "Interstate level"
  - Distribution- "Secondary road level"
  - On-site- "Driveway level"

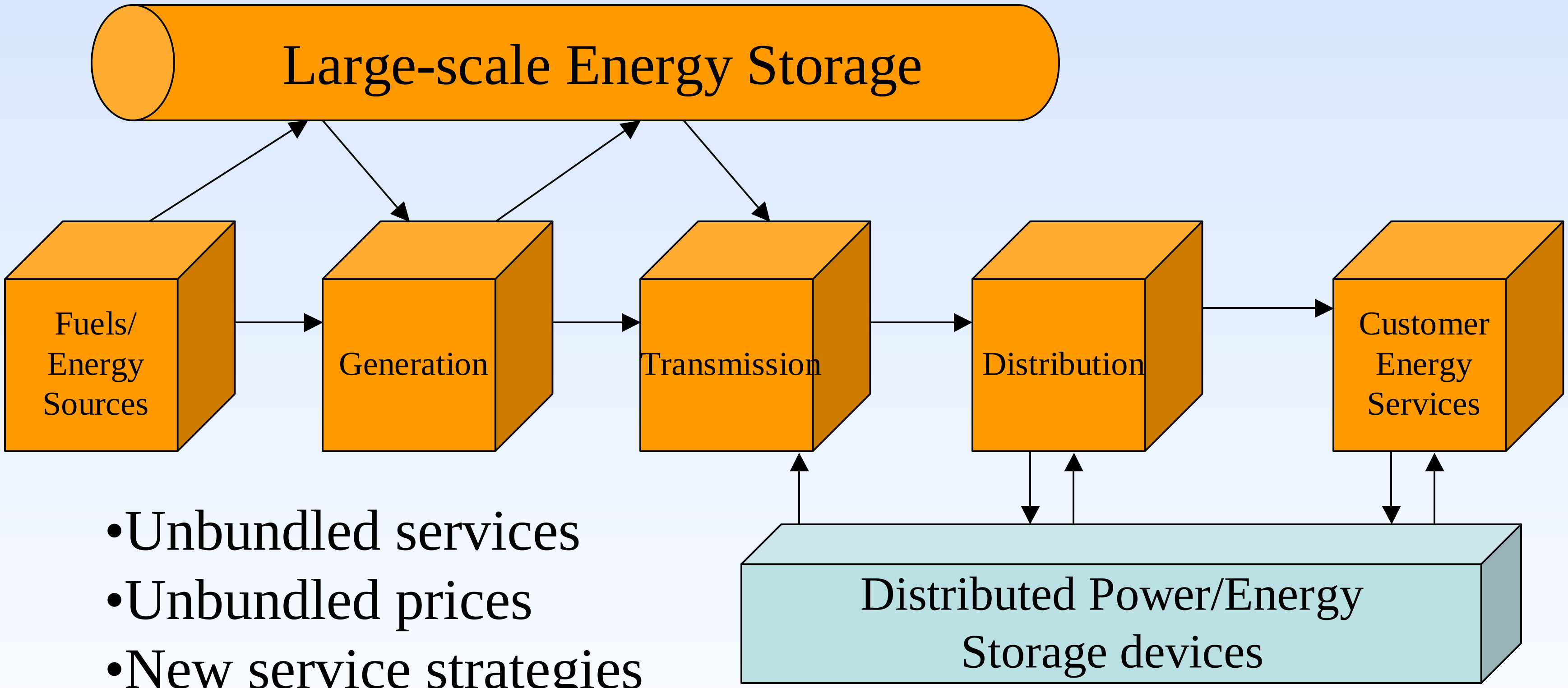
Five Dimensions of the “Old” Electricity Value Chain



Traditional way: Regulated utility bundled functions:

One price does all.

Six Dimensions of the "New" Electricity Value Chain



- Unbundled services
- Unbundled prices
- New service strategies

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A New World Order for Electricity

Wholesale market

- Fully deregulated
- Significant hedging/trading
- Energy storage for arbitrage
- Flexible/truly dispatchable power stations (coal, gas)
- New private DC lines
- Conversion to some private AC Transmission
- **FLEXIBILITY, COMMODITY MARKET MENTALITY. ARBITRAGE-DRIVEN**

Retail market

- Mostly deregulated
- Distributed power, micro-, mini-grids
- Distributed energy storage devices
- Natural-gas driven
- **CUSTOMER-DRIVEN SERVICES**
- Demand-side conservation
- Little trading and hedging (except big-load customers
- Power quality management

The Electricity Infrastructure BACKBONE

- Mostly regulated or large government role
- Energy storage for ancillary services/security/assurance
- Low cost but inflexible baseload stations (coal, nuclear)
- Fee-for-service
- **RELIABILITY AND SECURITY DRIVEN**
- Incremental rates of return over costs

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Analogies in Other Industries

- Federal Reserve—regulated money supply, supports banking infrastructure
- Fannie Mae/Freddie Mac—privatized gov't orgs regulate mortgages, supports real estate industry
- Interstate highways—supports transportation
- FAA-funded airports—supports airlines and travel industry
- Blue Cross/Blue Shield—backstops health and medical insurance
- Internet—government funded network, supports e-commerce and IT industries

"Issues" That Don't Show Up In Theoretical Market Designs

- Herd mentality and irrational exuberance
- Grossly inadequate investment in the infrastructure backbone (large generation assets, transmission facilities)
- Who pays for the infrastructure backbone?
- Transmission system built for reliability (minimal transfers of bulk power flows) not transaction-based power flows over long distances.
- "Real-time" costs are a fiction
- Technology development costs paid by users?

Have We Lost Sight of the Goals?

DEREGULATION WAS TO:

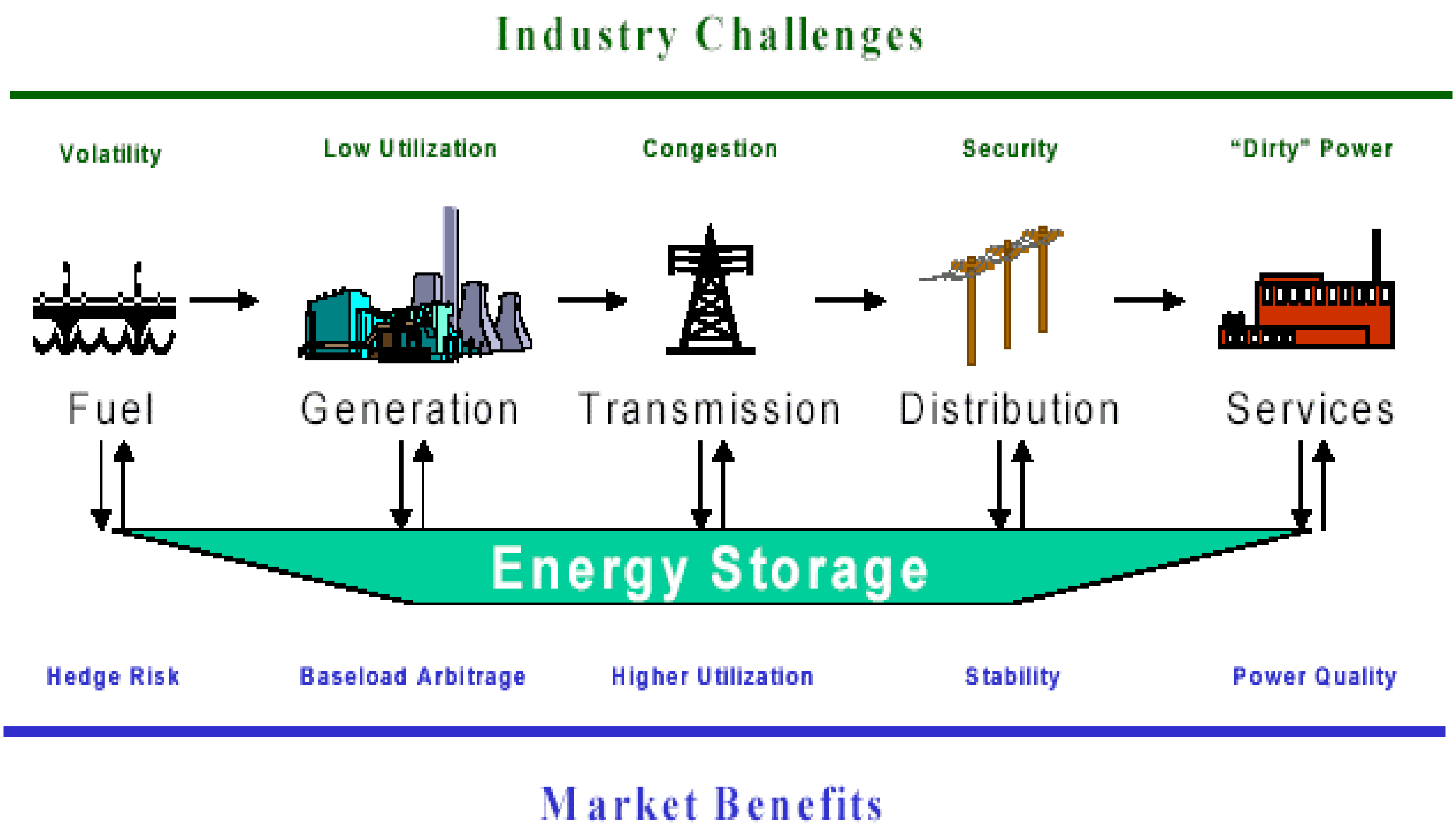
- Encourage competition but provide safety net
- Reduce prices to consumers
- Optimize existing infrastructure
- Raise productivity of organizations and assets
- Encourage services and allows new technology to flourish.

New Goal: Infrastructure Security

- The way deregulation and competition unfolds is changing (regressing?) in the post-Enron financial regime.
  - State programs have backtracked or stalled
  - Merchant generation and trading sectors are in shambles
  - FERC is struggling to keep focus on competitive transmission organizations
- The need to secure the nation’s electricity infrastructure has now become a critical objective in the post-9/11 world.

Benefits of Energy Storage

Along the Electricity Value Chain



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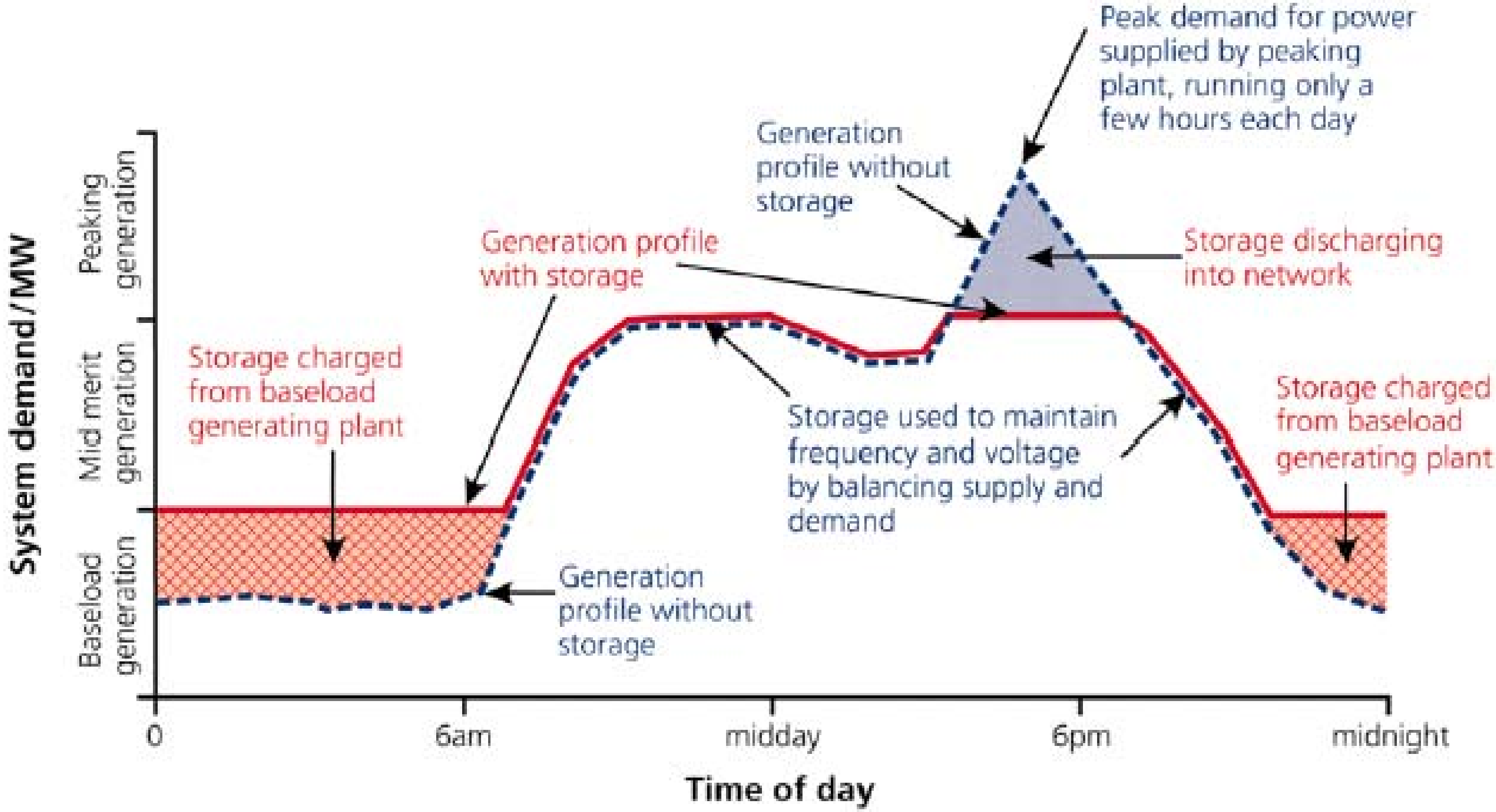
Load Profile of a Large-Scale Energy Storage Facility



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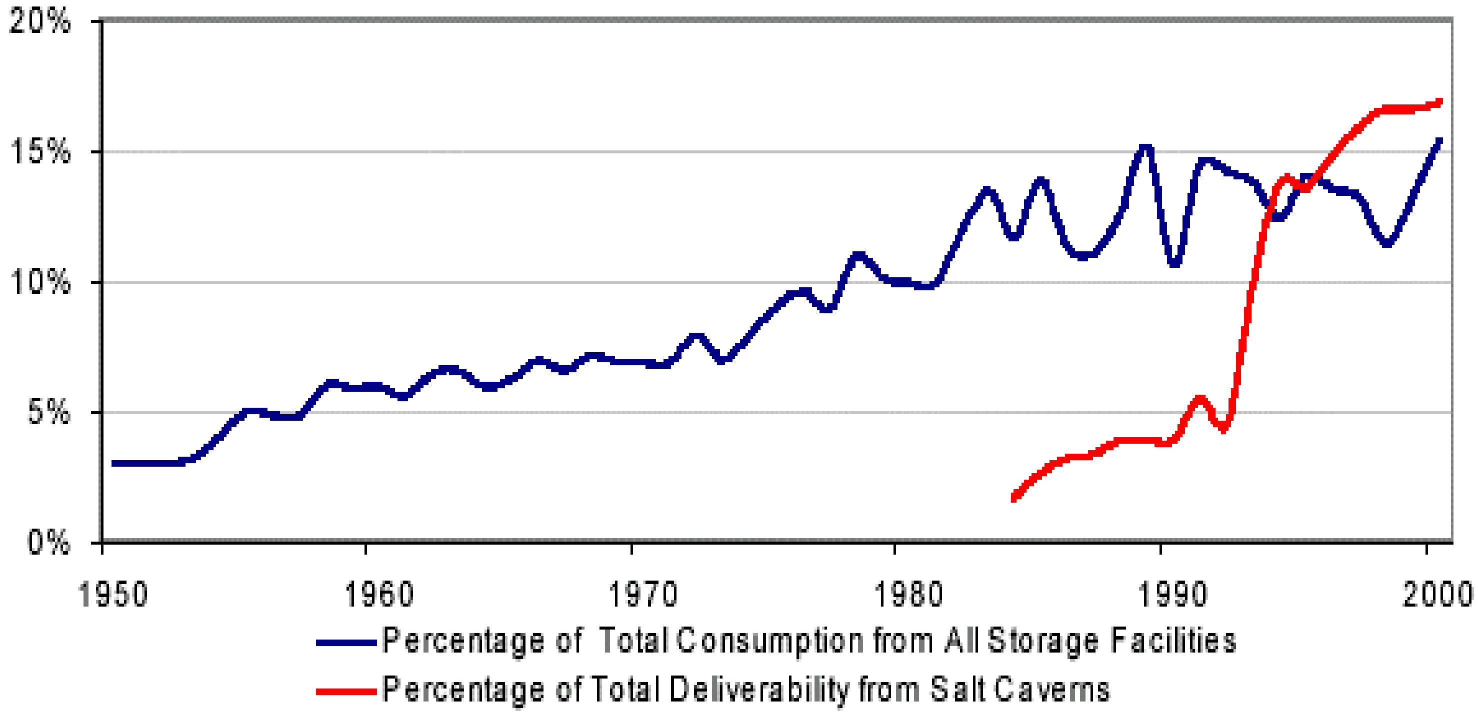
Storage's Changing Impact on the Gas Industry

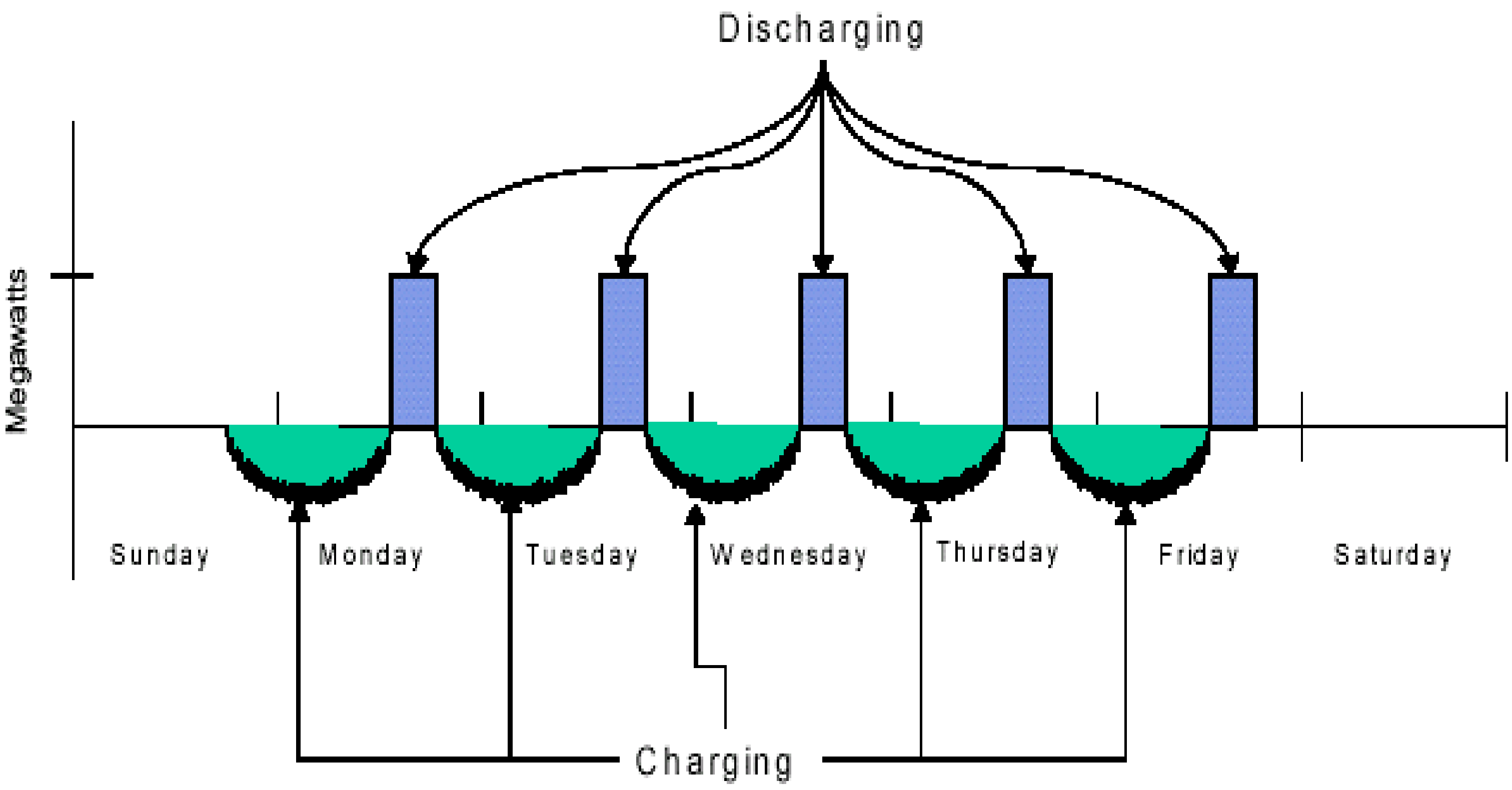


Energy Storage Value Buckets

- Arbitrage-storing and moving low-cost power into higher price markets, reducing peak power prices.
- Security and assurance-voltage regulation, black start, frequency control, emergency power.
- Asset optimization–reducing the cycling and dispatch of large fossil units meant for baseload.
- Enhancing renewables –transforming “take it when you can get it” into scheduled power. A fuel-free electricity source in the peak markets! (Also, daily wind resource curves are often opposite the daily load demand curves)
- Transmission asset deferrals –postpone the need for new transmission assets depending on where storage assets are placed.
- Support distributed generation –Micro- mini-grids and on-site power systems must become at least as reliable as traditional grid-supplied electricity. Today’s digital society/economy demands power quality several orders of magnitude higher. Storage assets placed at distribution-voltage substations and integrated into advanced DG devices and uninterruptible power systems

Renewable Energy Sales into Peak Market Prices

With Energy Storage



Issues for Wind Customers*

- **Backing down generation to accommodate wind**
- **Frequency/System reliability issues**
- **Low capacity utilization on required transmission upgrades**
- **Significant amount of power being delivered off-peak**
- **Transmission constraints**

- **Implications**

- **Higher capital costs**
- **Higher ancillary service costs**
- **Lost renewable energy credits**
- **Higher O&M costs**
- **Higher risk management/planning costs**
- **Loss of low-cost power production capacity**

*Slide courtesy of Ridge Energy Storage

Issues for Wind Generators*

- **Non-dispatchable power**
- **Non-firm power**
- **Transmission constraints**
- **Low capacity utilization on required upgrades (substations, etc.)**
- **Potential for restrictions on instantaneous power deviations**

- **Implications**

- **Lost sales**
- **Lost PTC's/renewable energy credits**
- **Limited ability to earn capacity fees**
- **Higher capital costs**
- **Minimum pricing for power delivered**

*Slide Courtesy of
Ridge Energy Services

Unlocking the Value of Energy Storage

- System and economic modeling of the electricity network with storage facilities added.
  - Large storage facilities (greater than 500 MW) added in strategic parts of the country for *national* infrastructure security and assurance/reliability. What is the impact on the system and after significant "system events?" The "INTERSTATE" Transmission level
  - Mid-sized facilities (10-500 MW) added to bolster regional infrastructure. "SECONDARY ROADS" or distribution level
  - Local and on-site facilities to enhance distributed generation, uninterruptible power, etc. "DRIVEWAYS" or on-site level

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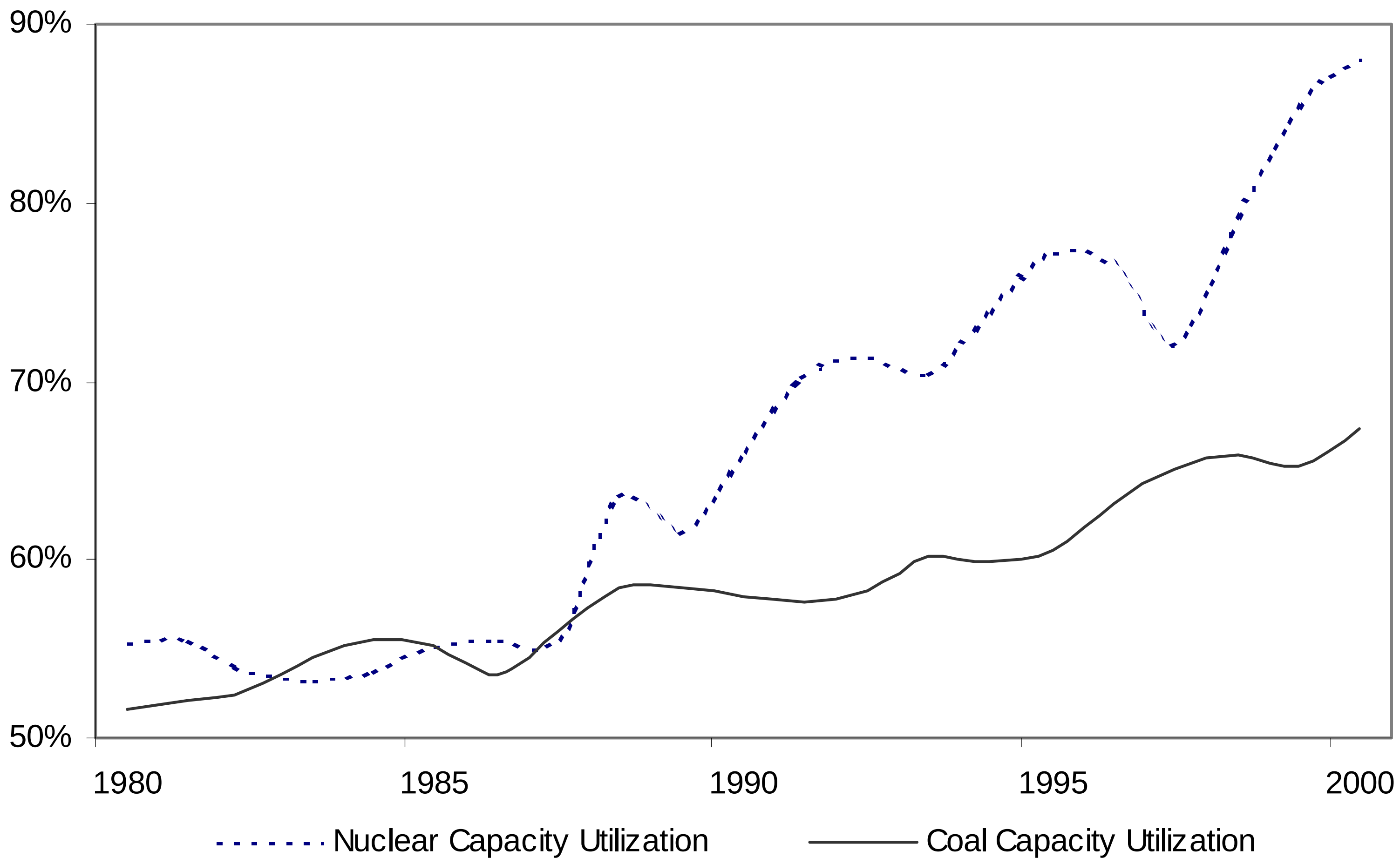
Coal Facilities Lag Nuclear Unit Improvements



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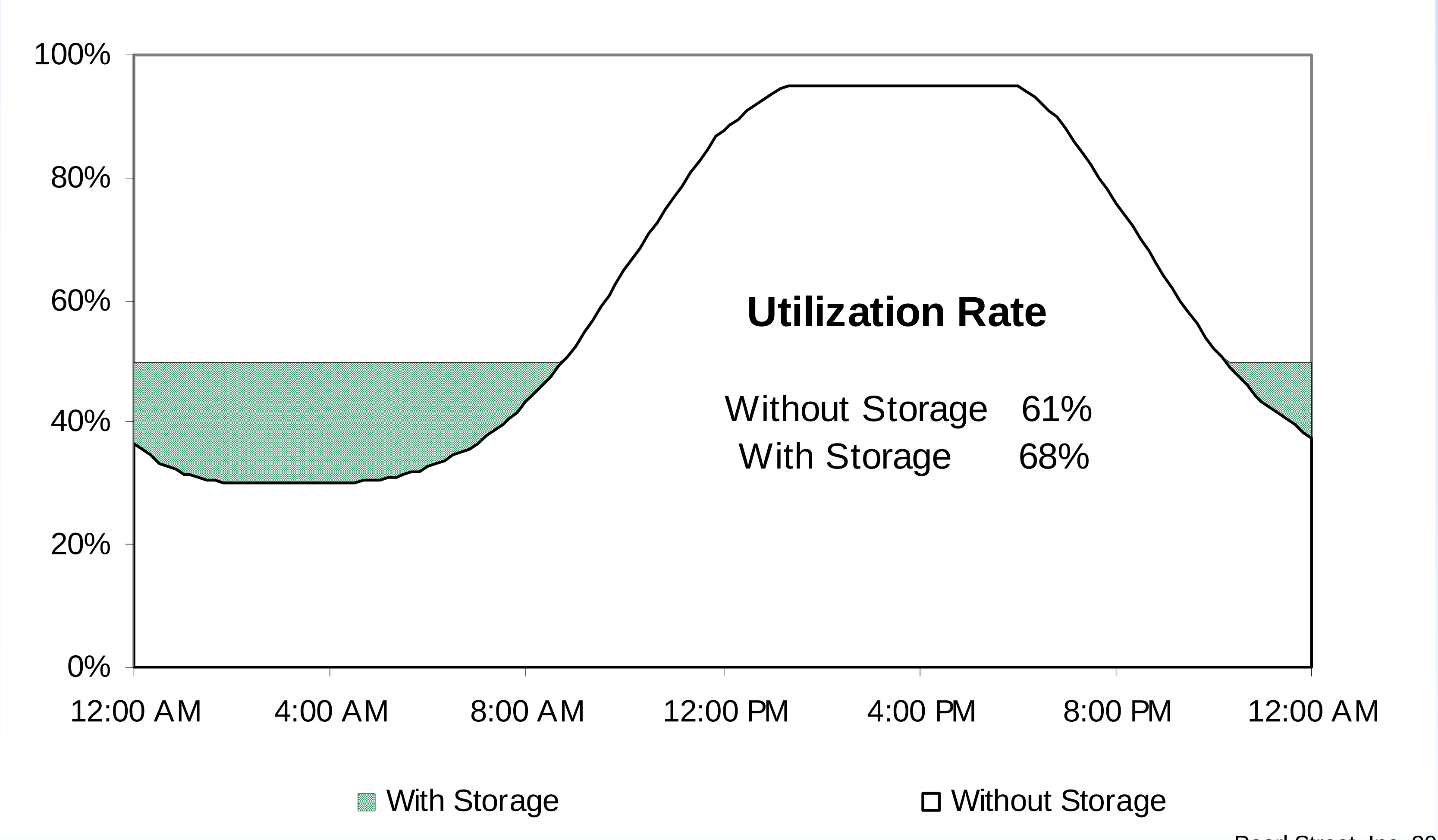
Coal Generation Benefits from Storage Facilities



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Minimum Storage as a National Goal

- The U.S. has 2.7% of its generating assets embodied by storage (all pumped storage hydroelectric except for 110-MW CAES) and this is declining as we add capacity but do not add storage.

- Other economically developed countries have larger percentages (4-10%) and some are working towards even larger goals.

- Given the new regime, should the government set a national goal or guideline? SYSTEM AND ECONOMIC MODELING CAN ANSWER THIS QUESTION!

- Does the electric infrastructure deserve a stored resource similar to the National Petroleum Reserve?

- Does distributed generation + storage lead to a more robust, secure electric grid? SYSTEM AND ECONOMIC MODELING CAN ANSWER THIS QUESTION!

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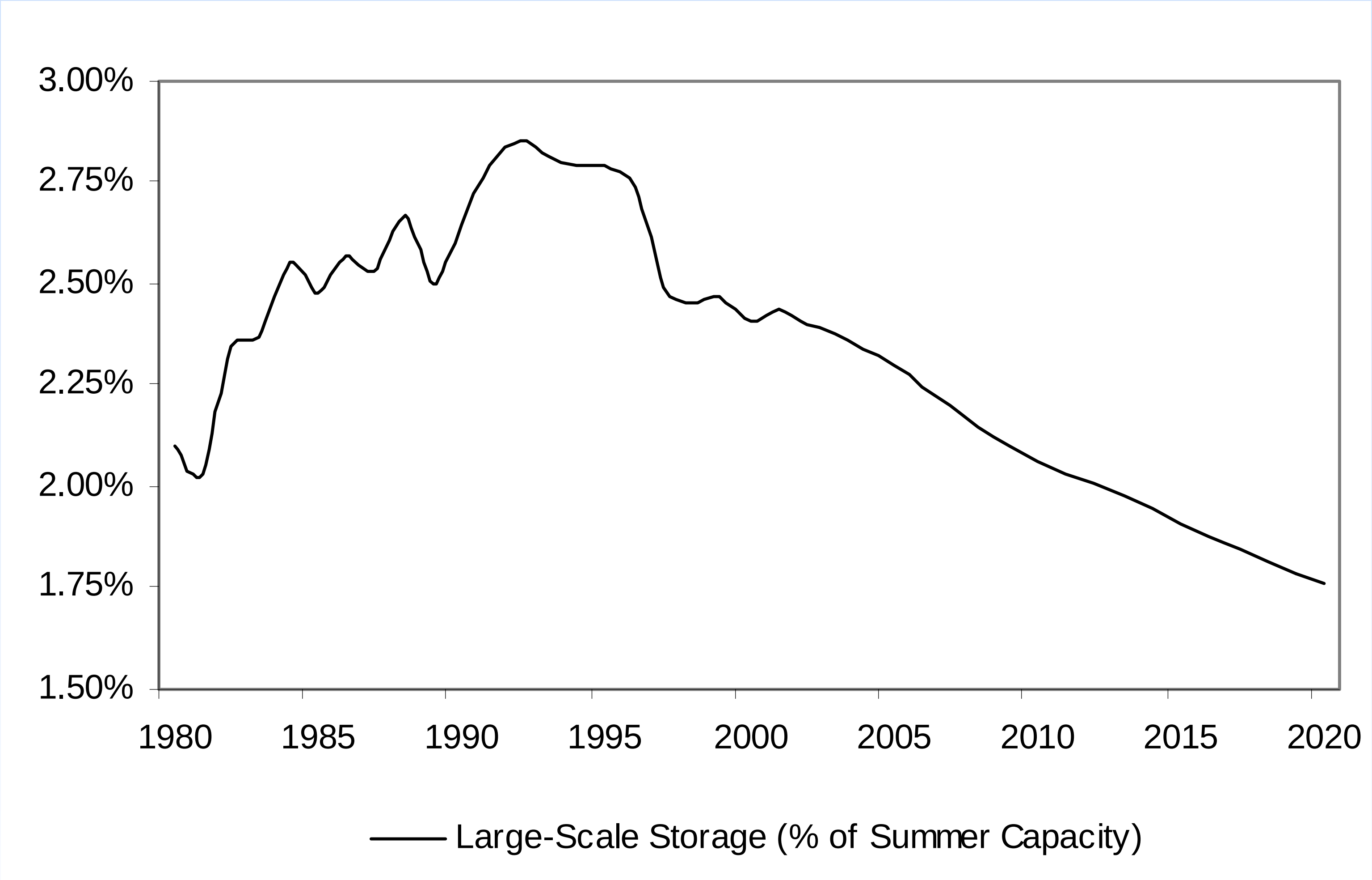
Large-Scale Energy Storage Representation Declines



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Pumped Storage Capacity Wanes

- Large-scale storage solution to date has been pumped storage hydroelectric, BUT:
  - Last facility to come on-line was Rocky Mountain in Georgia. Project took 20 years
  - Proposed facilities in New Jersey, Missouri, California, elsewhere have been scuttled because of public opposition
  - Technology is commercial but outdated

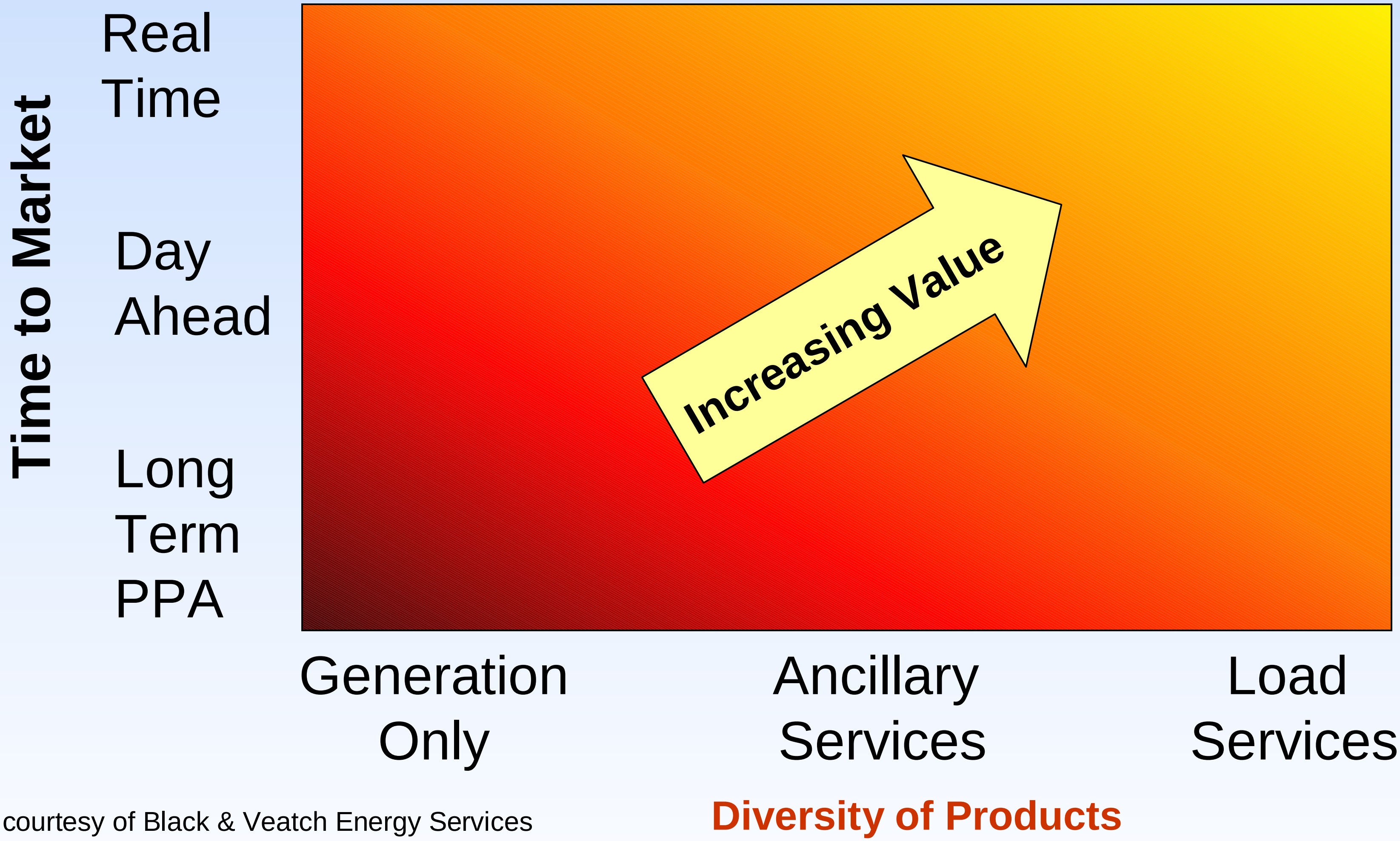
If storage is so great, why isn't it more prevalent?

- Despite deregulation, industry is still not financially motivated to optimize assets and reduce costs
- Herd mentality-regulated industry tends towards lowest risk ("If everyone else is doing it, I can't get into trouble."
  - Nuclear plants in the 1970s
  - Independent power in the 1980s
  - Gas-turbine combined cycles 1997-2001
- Overhang from the gas turbine boom means excess capacity in most areas of the country
- Costs for many storage technologies, particularly in the mid-range, are high because of an immature market, development, and value buckets that have yet to be accurately illuminated (e.g. ancillary services)
- Value of storage is greatest in the benefits that are most subjective and hardest to quantify.
  - Ancillary services
  - National security
  - Rapid response

If storage is so great, why isn't it prevalent? (cont.)

- Greater grid security-what is the value?
  - And who is willing to pay for it?
- Operating flexibility-what is the value?
  - Flexible units will capture value missed by other facilities, but difficult to predict
- Ancillary Services-what is the value?
  - In competitive markets, this value is being illuminated but what about rest of the country?
    - Regulation, spinning reserves, non-spinning reserves, replacement reserves, black start

General Findings of CAES Studies*



*Slide courtesy of Black & Veatch Energy Services

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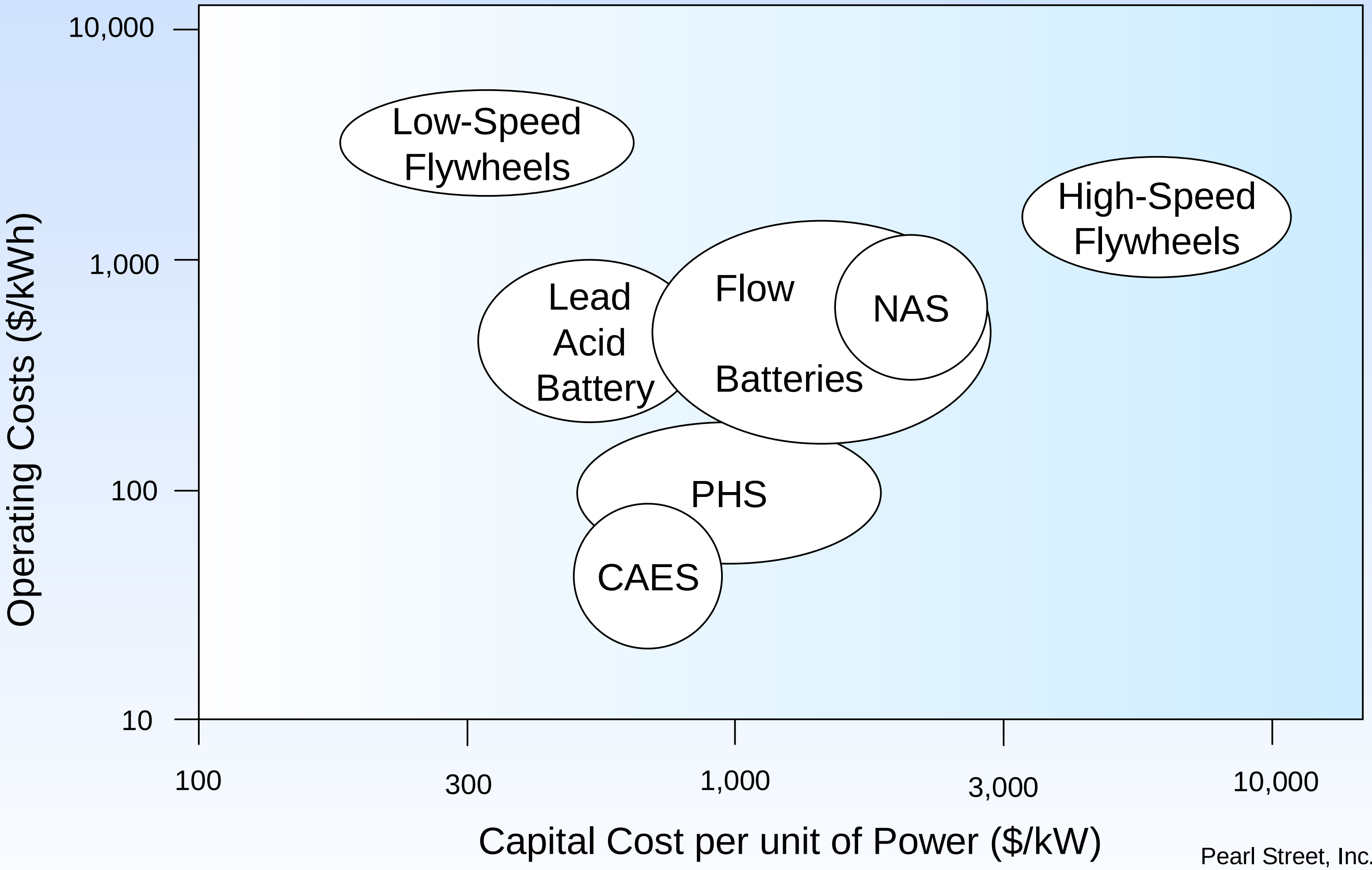
Distributed Storage Value Proposition

- Condition, performance of T&D assets are deteriorating
- Investment in T&D assets declining. Future investment jeopardized by regulatory dysfunction and uncertainty
- A network of mini- and micro-grids may provide a more secure infrastructure
- Power quality “events” cost industry tens of billions dollars each year
- Energy storage is a technology “bridge” between UPS and distributed generation. One integrated device can satisfy all on-site power needs and connect into the mini- or micro-grid.
- A GRID BUILT FOR THE INDUSTRIAL AGE IS NOT ADEQUATE FOR THE DIGITAL ECONOMY

Installation vs. Operating Costs



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Storage Technologies

UPS Market ←

1-MW **10-MW** **100-MW and above**

Flywheels
Batteries
Capacitors
Ultra-capacitors (combined with DG devices)

Large-scale batteries
Lead-acid
NAS
Va Redox

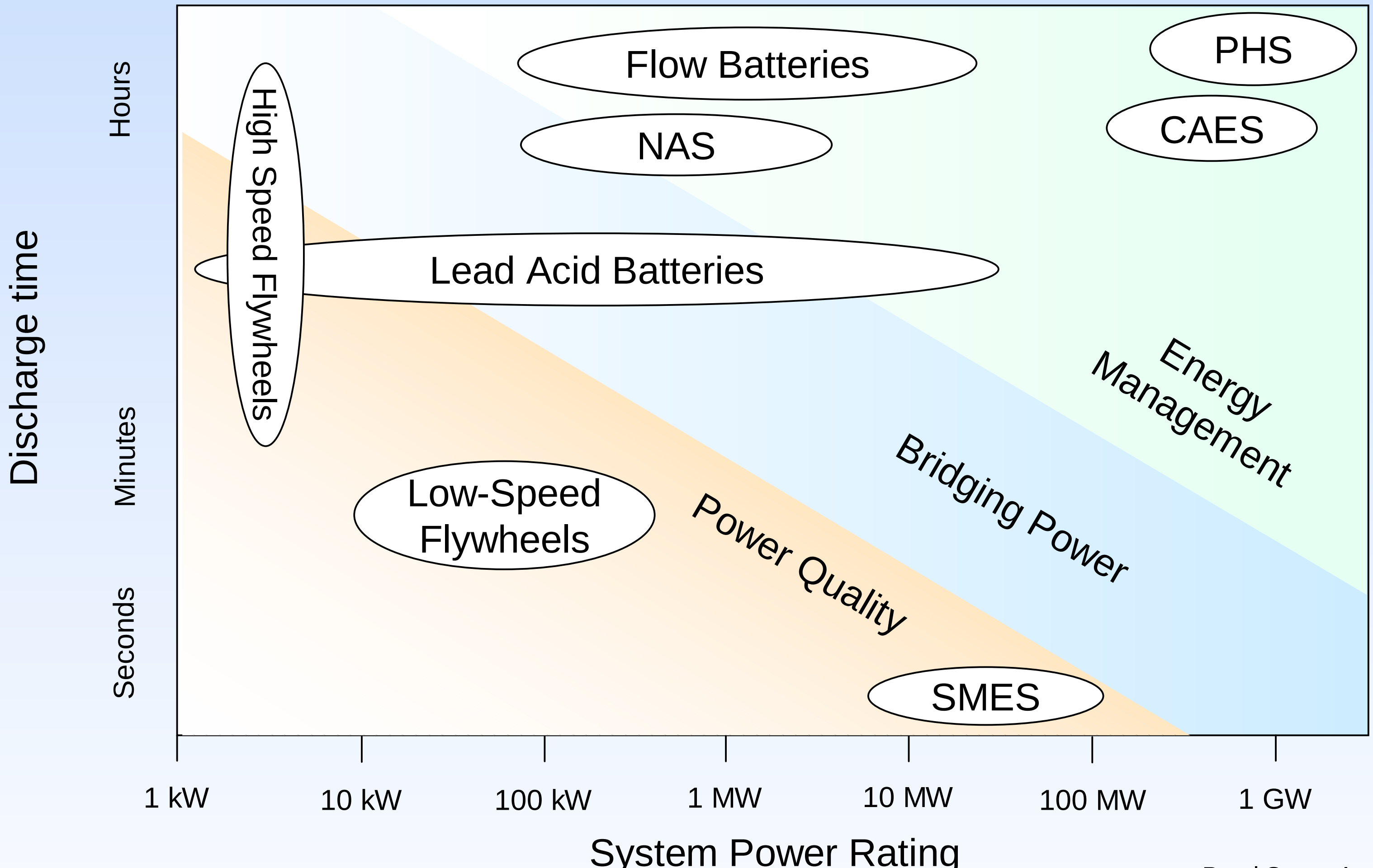
Reverse-flow fuel cells
Regenesys
Sub-surface CAES (underground pipe)

Pumped storage

Compressed Air Energy Storage (CAES)

Market Roles of Energy Storage Facilities

Based on Discharge Time vs. Power Rating



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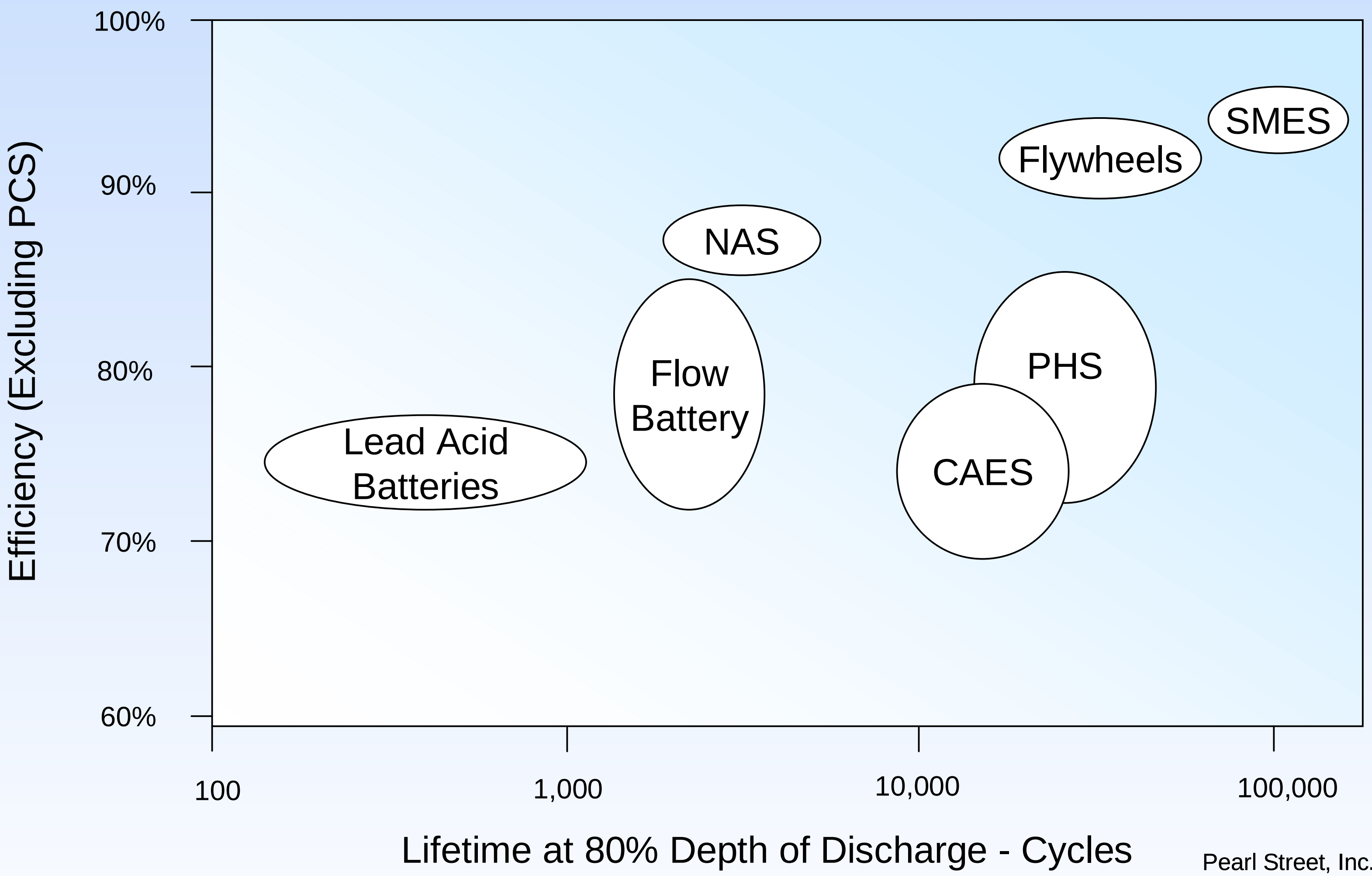
Efficiency vs. Discharge Endurance



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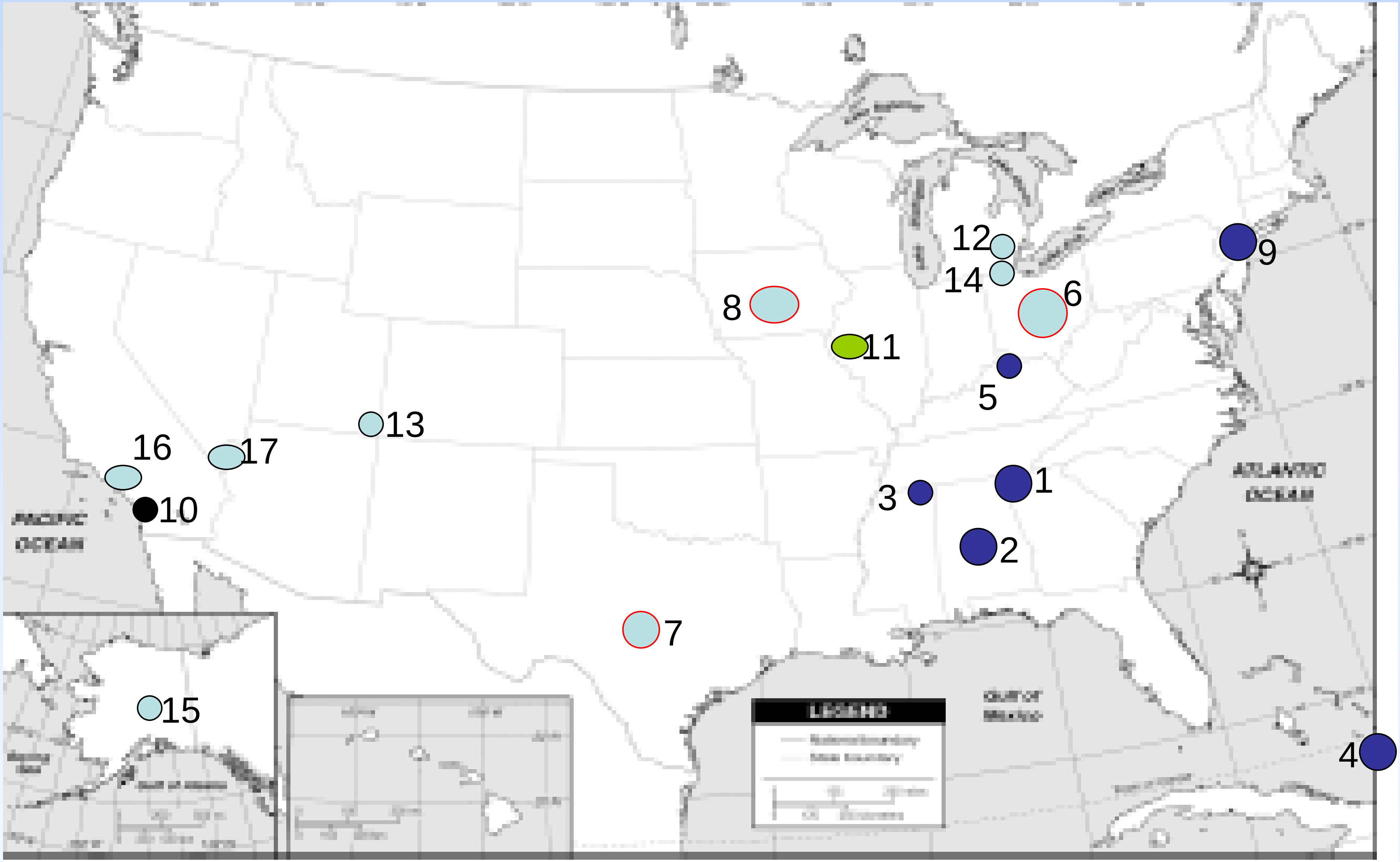

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Storage projects are operating and more are planned.

- 1. Operating-850-MW Rocky Mountain-last pumped storage to come on-line (note: many utilities currently operate such facilities) Oglethorpe Power
- 2. Operating. 110-MW CAES (Alabama Electric Cooperative) facility operating
- 3. Demonstration. 12 MW regenerative fuel cell (reverse flow battery) at TVA-near or in startup
- 4. Operating. 20 MW lead-acid battery facility operating in Puerto Rico Electric Power Authority
- 5. Demonstration. 500 kW Sodium sulfur reverse flow battery operating at American Electric Power
- 6. Active. Norton CAES facility, up to 2700 MW of storage
- 7. Active. Markham CAES 540-MW permitted facility
- 8. Active. Eagle Grove aquifer-based CAES between 100-200 MW serving regional wind facilities.
- 9. Operating. 1-MW flywheel facility serving rail transportation.
- 10. Decommissioned. 10-MW lead-acid battery facility in Chino, California.

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Storage projects are operating and several more are planned. (cont.)

- 11. Proposed. Commercial and/or technology demonstrations in central Illinois
- 12. Proposed. NextEnergy distributed power corridor in Detroit, demonstration of micro grid technologies, including storage such as flywheels.
- 13. Under construction. 250-kW Vanadium redox flow battery, Pacificorp
- 14. Under construction. 200-kW zinc bromide flow battery, Detroit Edison Co.
- 15. Under construction. Multi-MW battery facility. Golden Valley Electric
- 16. Operating. 3.5 MW valve regulated battery system.
- 17. Proposed. Multi-MW battery/flow-battery facility

- *List not mean to be all-inclusive but representative of projects and technologies