

Large-Scale Energy Storage Opportunities for Renewable Energy and Smart Grid

International Battery Association Meeting

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Presented by:

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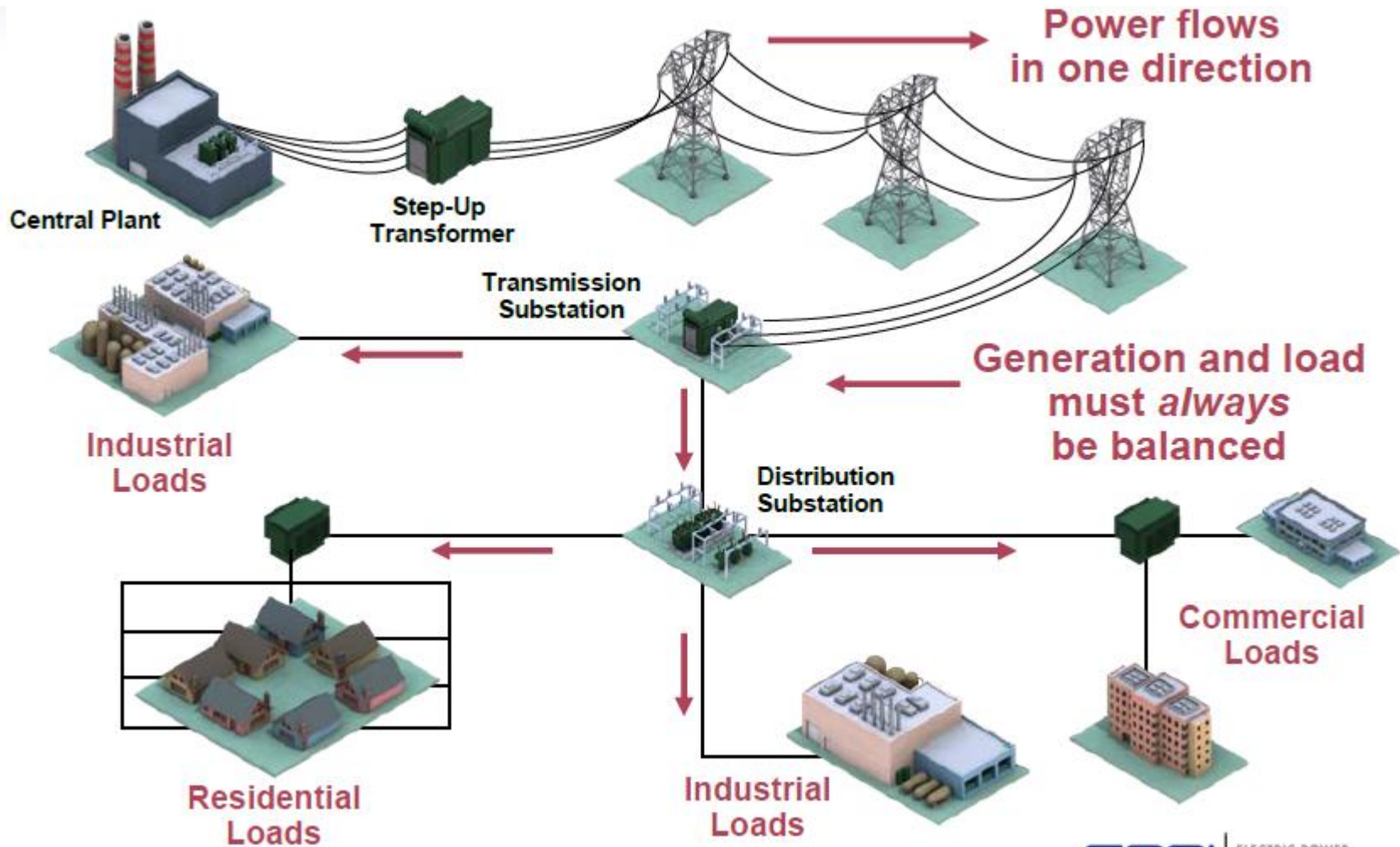


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U. S. Electric Grid

- 157,000 miles of high-voltage (greater than 230 kilovolts) electric transmission lines.
- Over 15,000 generating units
- 143 million customers.
- **Total Electricity Revenues in 2009 - \$353 B**
- There are more than 3,100 electric utilities in the United States.
 - 213 stockholder-owned utilities that provide power to about 73% of the customers
 - 2,000 public utilities run by state and local government agencies that provide power to about 15% of the customers
 - 930 electric cooperatives providing power to about 12% of the customers
 - 2,100 nonutility power producers, including both independent power companies and customer-owned distributed energy facilities.

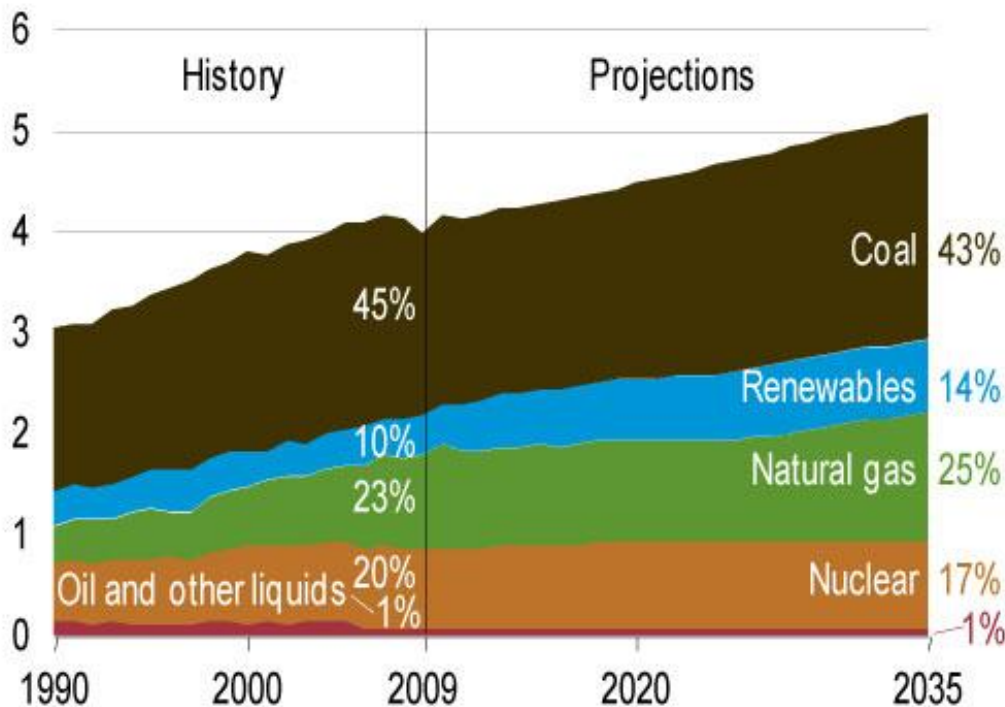
Today's Electricity Infrastructure



Supply Chases Demand

Figure 12. Electricity generation by fuel, 1990-2035)

Net electricity generation (trillion kilowatthours per year)

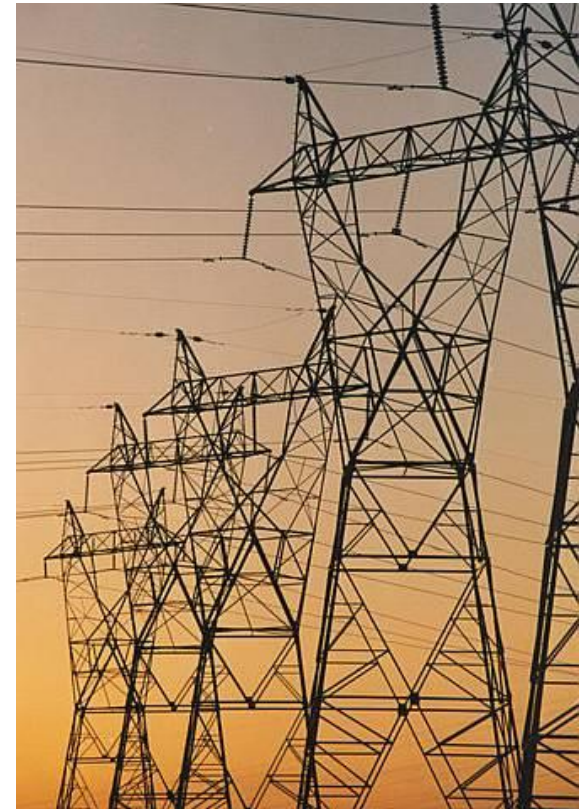


- ▶ Grid designed for peak power requirements
- ▶ New T&D infrastructure difficult to build
- ▶ Renewable Portfolio Standards changing generation mix
- ▶ Wind Capacity up to 34 GW

Source: AEO2011 Early Release Overview

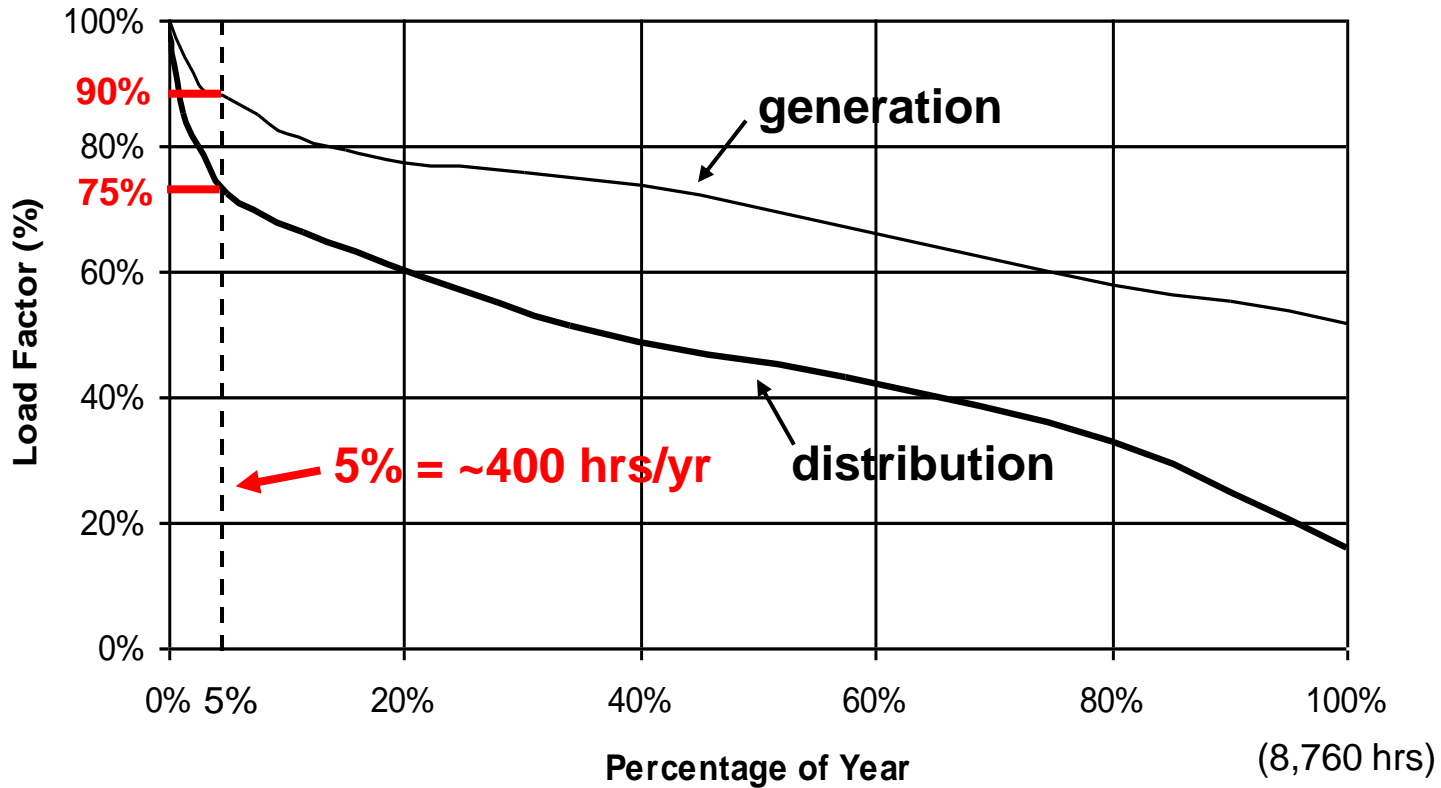
What's Changed? Why Energy Storage for Grid Applications Now?

- ▶ High cost of managing peak demands
- ▶ Increased deployment of renewables
- ▶ High cost of Transmission & Distribution infrastructure
- ▶ Improve asset utilization
- ▶ Investments in “smart grid infrastructure”

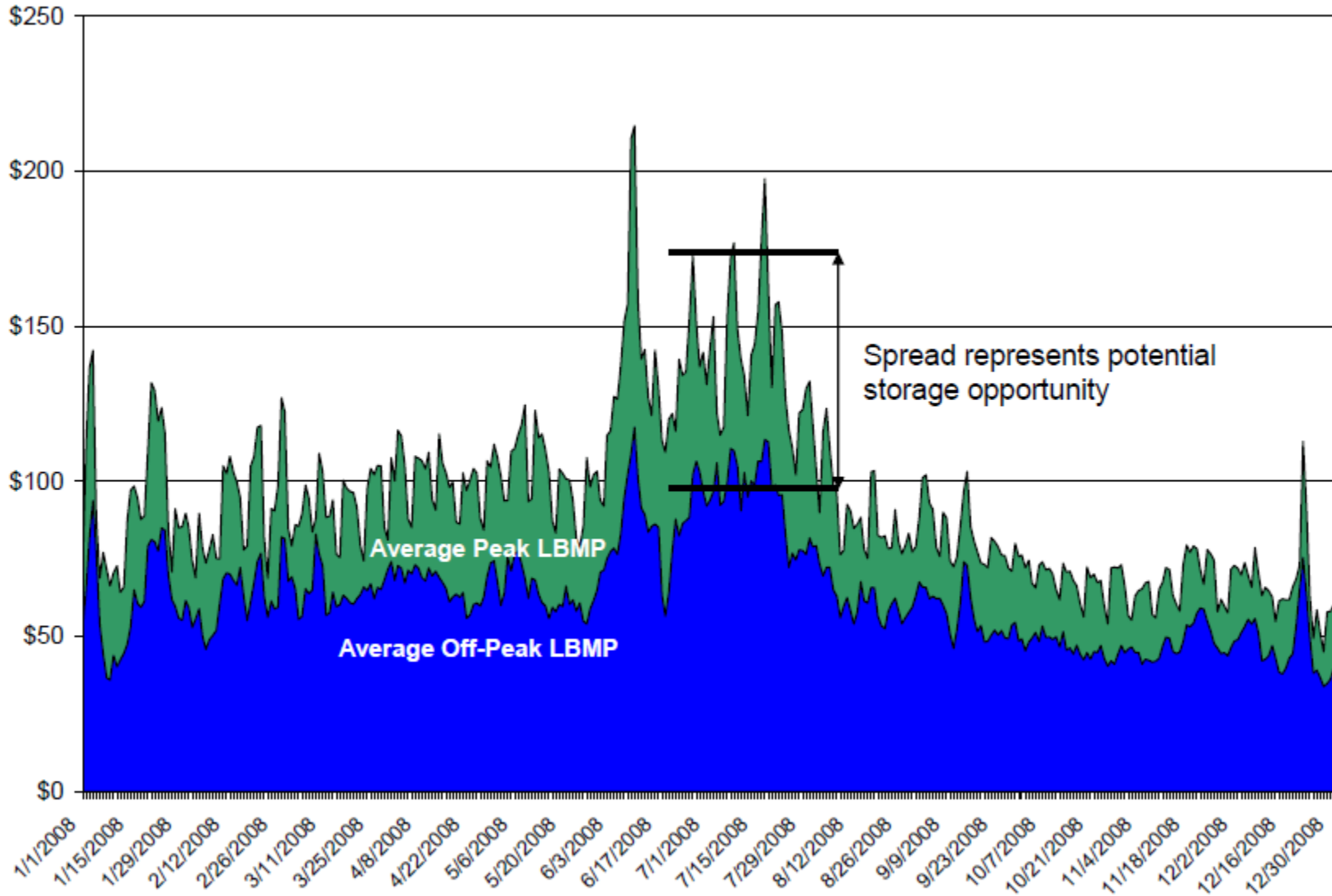


Grid Infrastructure Built for Peak – but Peak only used small percentage of the time!!

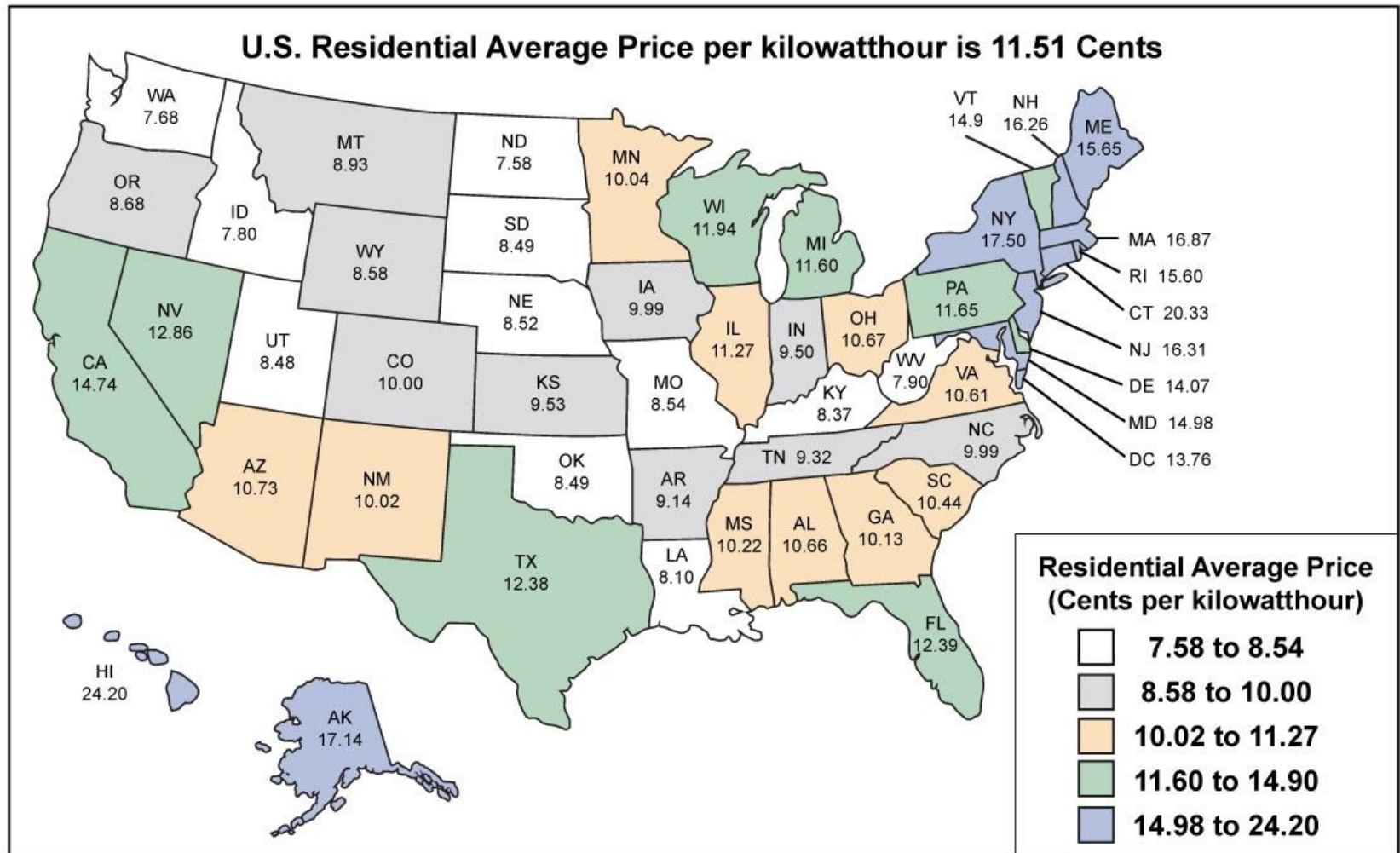
Hourly Loads as Fraction of Peak, Sorted from Highest to Lowest



Peak vs Off-Peak Price of Electricity



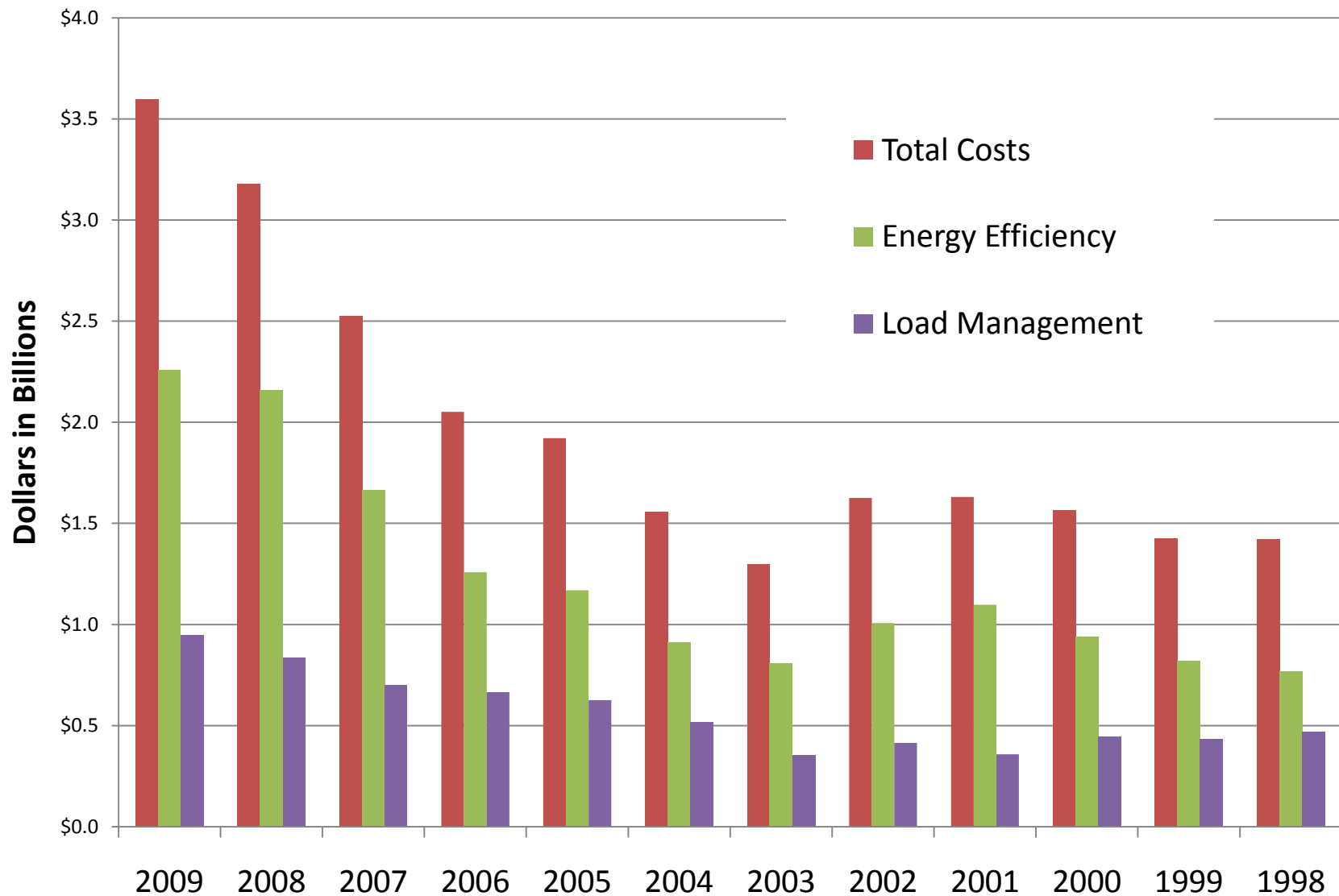
The Value of Energy Storage will vary by Location!!!!



Note: Data are displayed as 5 groups of 10 States and the District of Columbia.

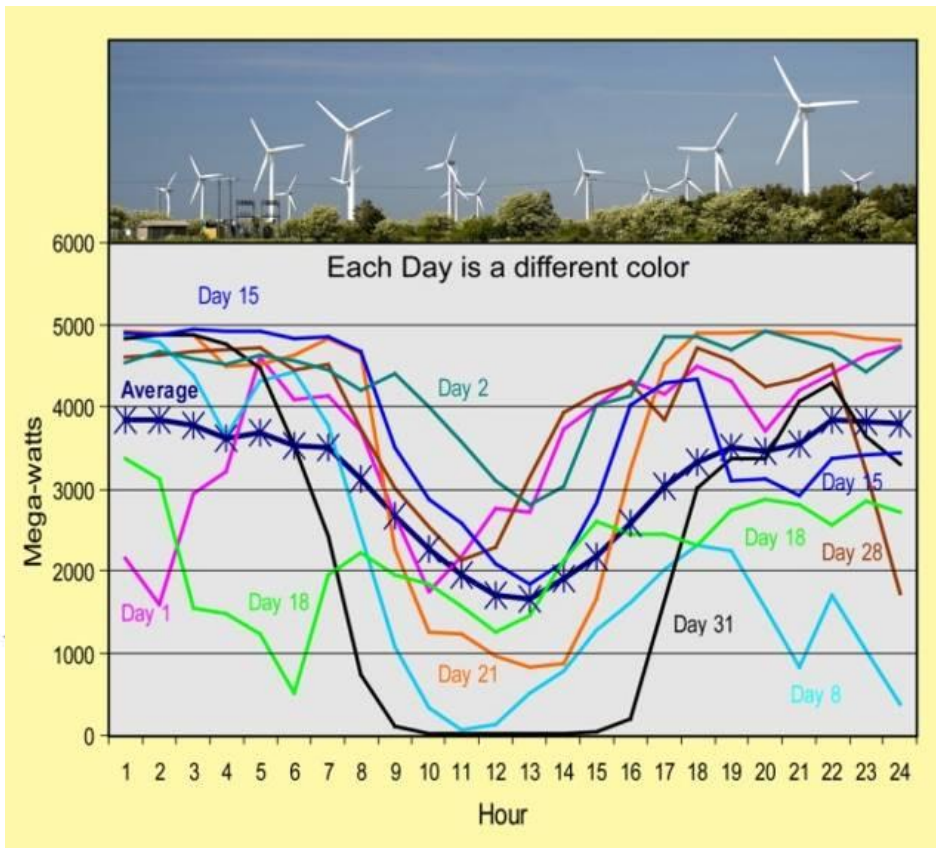
Source: U.S. Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report."

\$3.5 Billion Spent in 2009 on Demand-Side Management



Wind Power – Creates Regional Challenge

State Rankings for Wind Power in 2009



- ▶ 34.3 GW installed in U.S.
- ▶ 3.3 % of U.S. total
- ▶ Four states account for 51%
 - Texas, 9.4 GW
 - Iowa, 3.4 GW
 - California, 2.7 GW
 - Washington , 2.0 GW
- ▶ Wind accounted for 63% of all new capacity in 2009

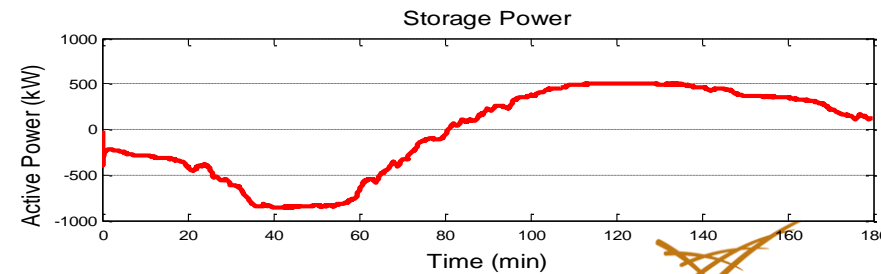
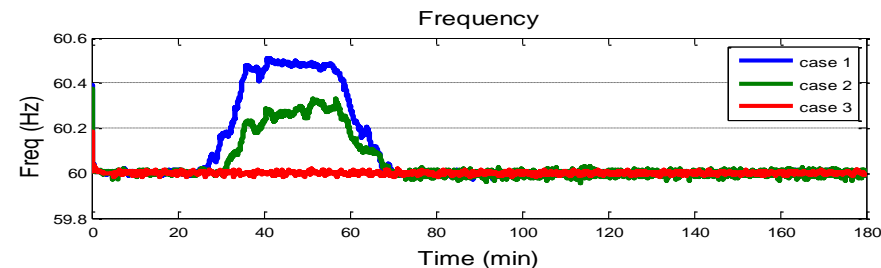
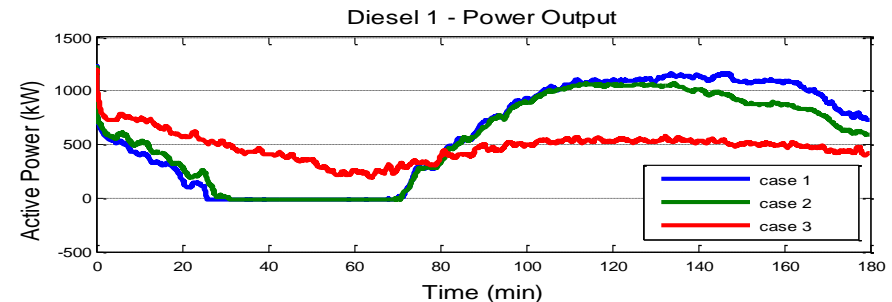
Control Strategies for Distributed Energy Resources to Maximize the Use of Wind Power in Rural Microgrids

- ▶ Three Scenarios Evaluated
 1. Wind + Diesel
 2. Wind + Diesel + Demand Response
 3. Diesel + Wind + Demand Response + Storage

Conclusions

DR and storage can both contribute substantially to the improvement

- ▶ frequency performance
- ▶ reduction of diesel generator movements, under high-wind normal operations
- ▶ generator contingencies in a low-wind scenario



Courtesy : Shuai Lu, Marcelo A. Elizondo, Nader Samaan, Karanjit Kalsi, Ebony Mayhorn, Ruisheng Diao, Chunlian Jin, Yu Zhang, Pacific Northwest National Laboratory

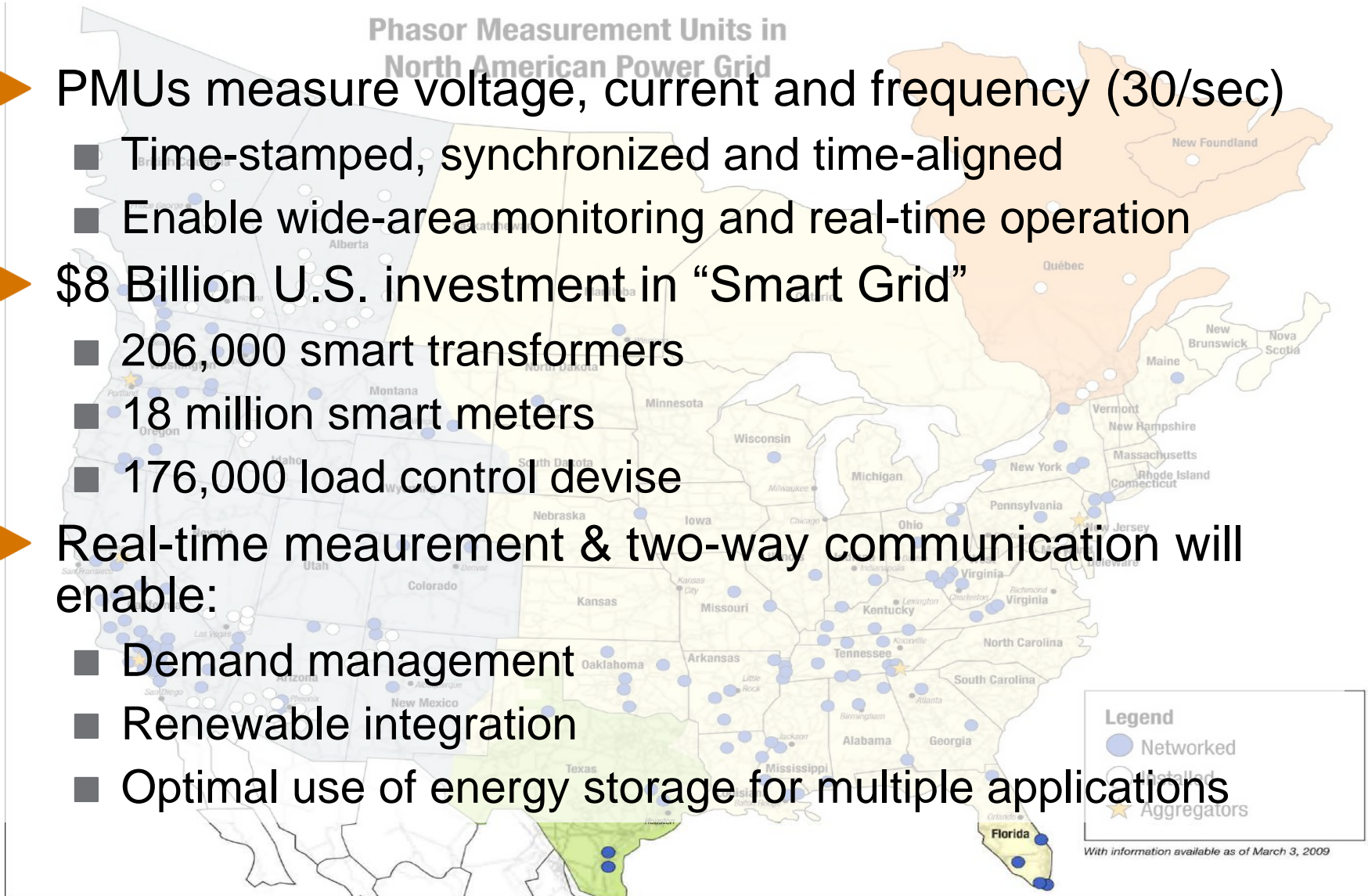
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Future Grid – Measurement & Communication

- ▶ PMUs measure voltage, current and frequency (30/sec)
 - Time-stamped, synchronized and time-aligned
 - Enable wide-area monitoring and real-time operation
- ▶ \$8 Billion U.S. investment in “Smart Grid”
 - 206,000 smart transformers
 - 18 million smart meters
 - 176,000 load control devices
- ▶ Real-time measurement & two-way communication will enable:
 - Demand management
 - Renewable integration
 - Optimal use of energy storage for multiple applications

Phasor Measurement Units in North American Power Grid



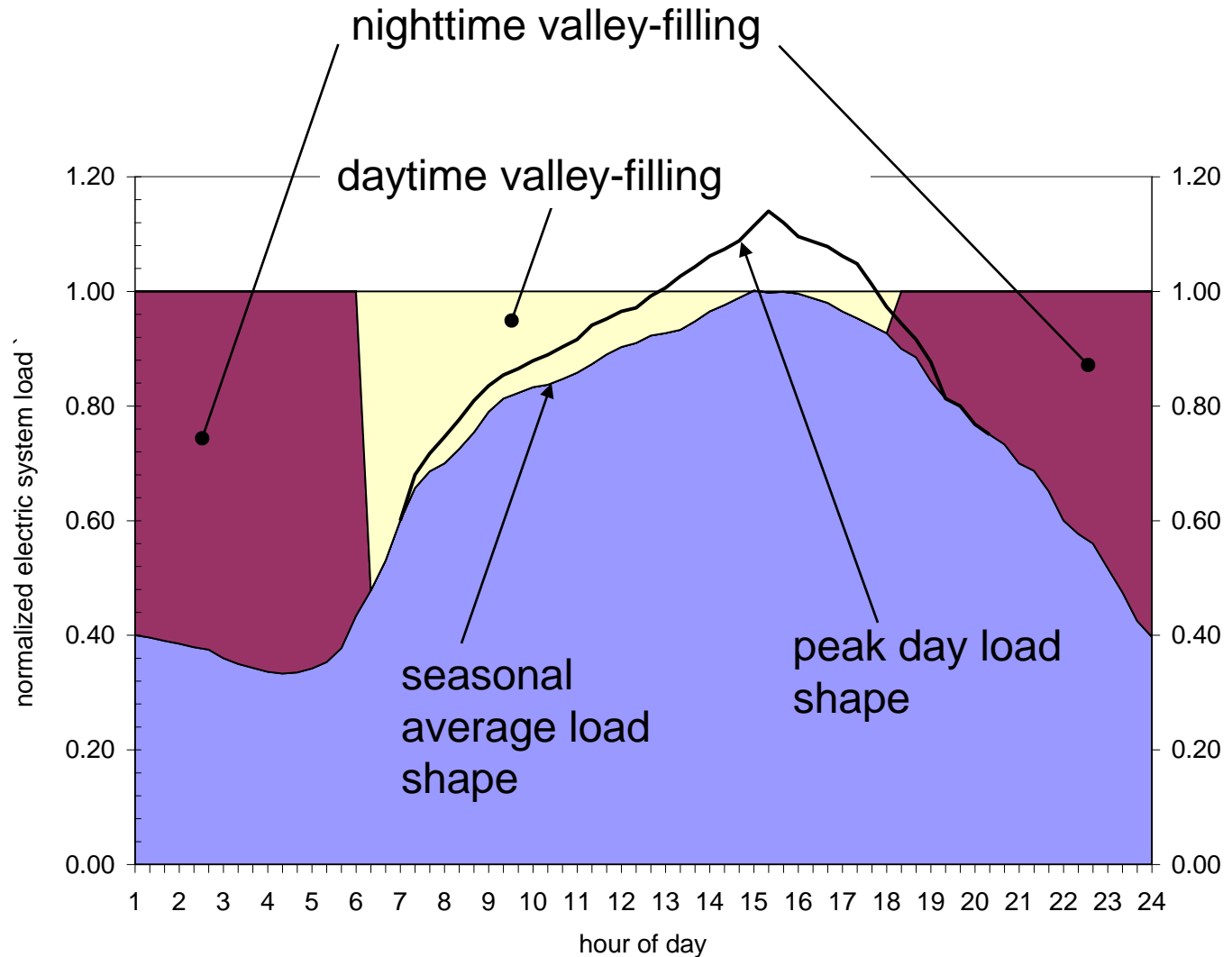
Legend

- Networked
- Controlled
- ★ Aggregators

With information available as of March 3, 2009

How Many PHEV Can You Put On Today's Grid?

- ▶ Use the average day in the peak season
- ▶ Determine size of valley in MWh
- ▶ Constrain valley by excluding
 - Hydro
 - All other renewables
 - Nuclear
 - Peaking plants

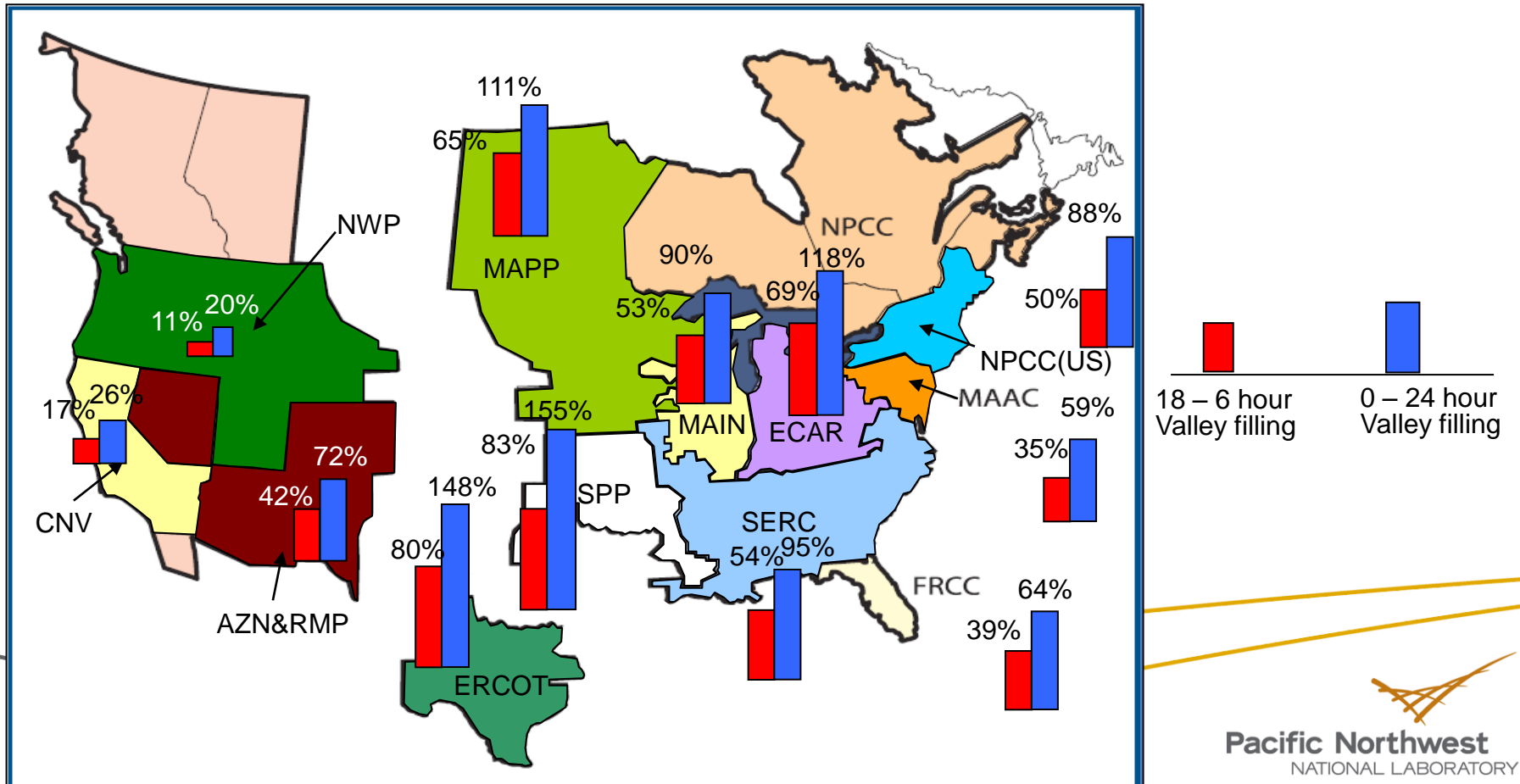


Regional Load Profile

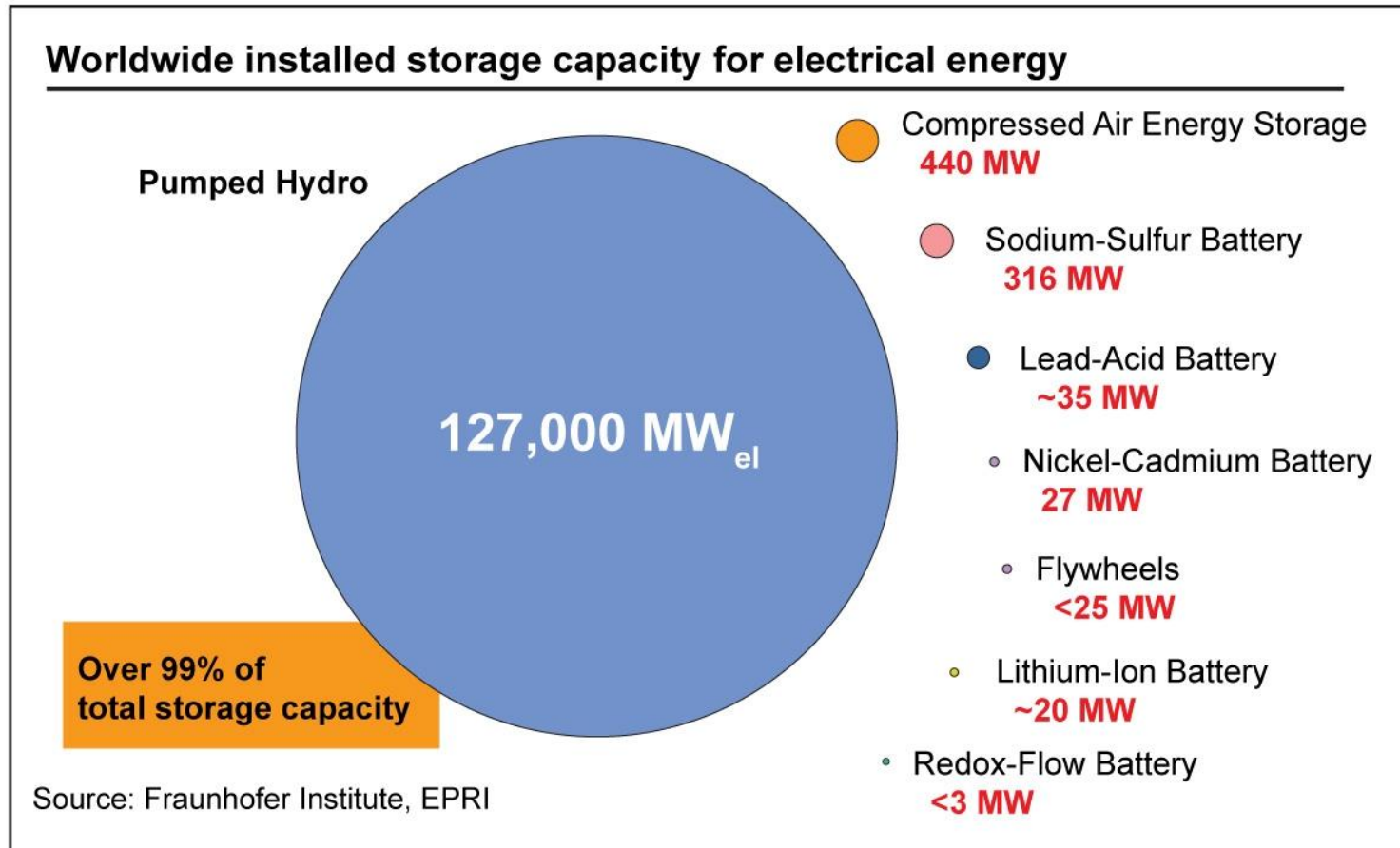
Potential for Fueling the Regional LDV Fleet with Available Electric Capacity ?

Midwest and Eastern regions: high available capacity

Western region: limited available capacity because of large hydro share

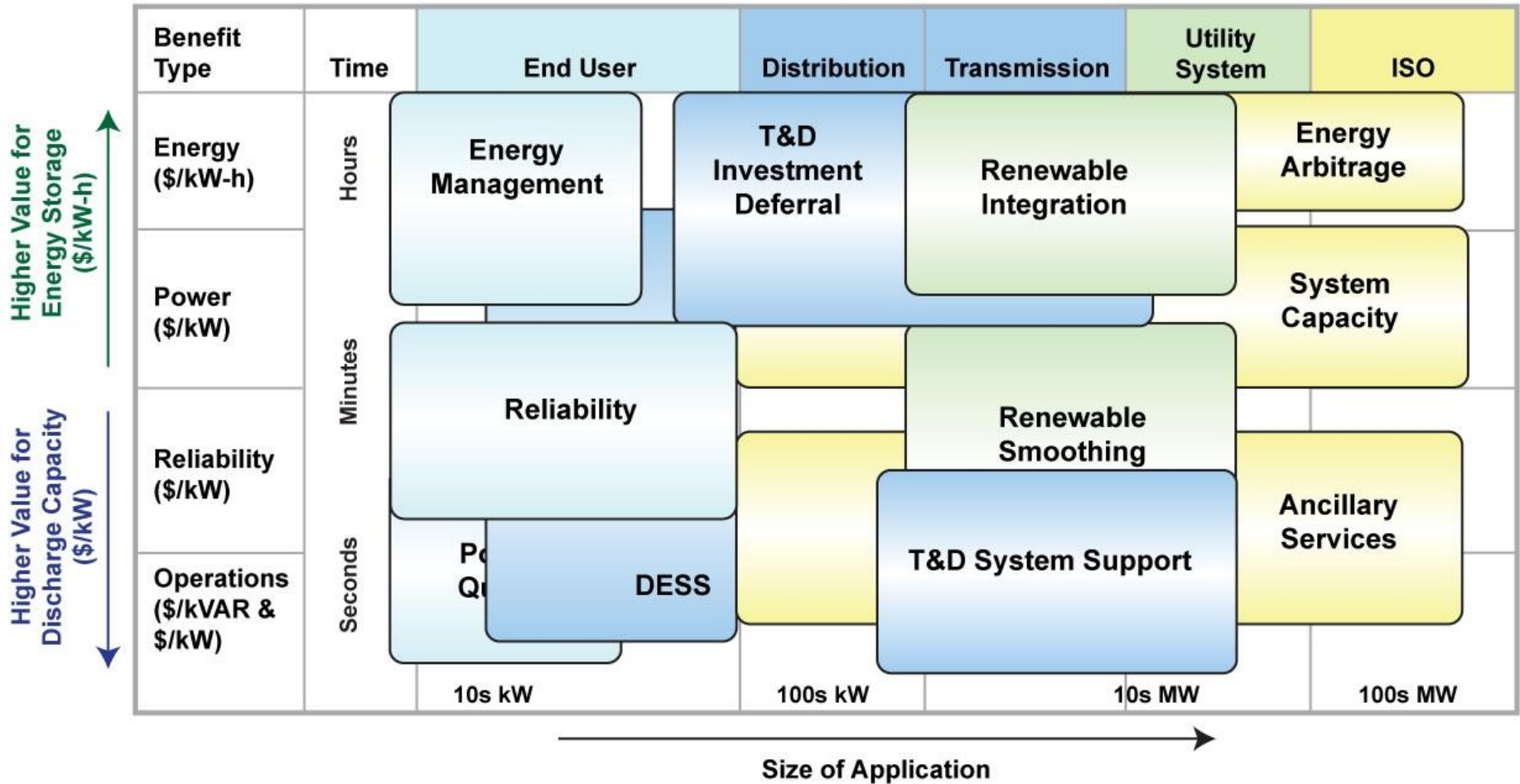


Worldwide Installed Storage Capacity for Electrical Energy Storage



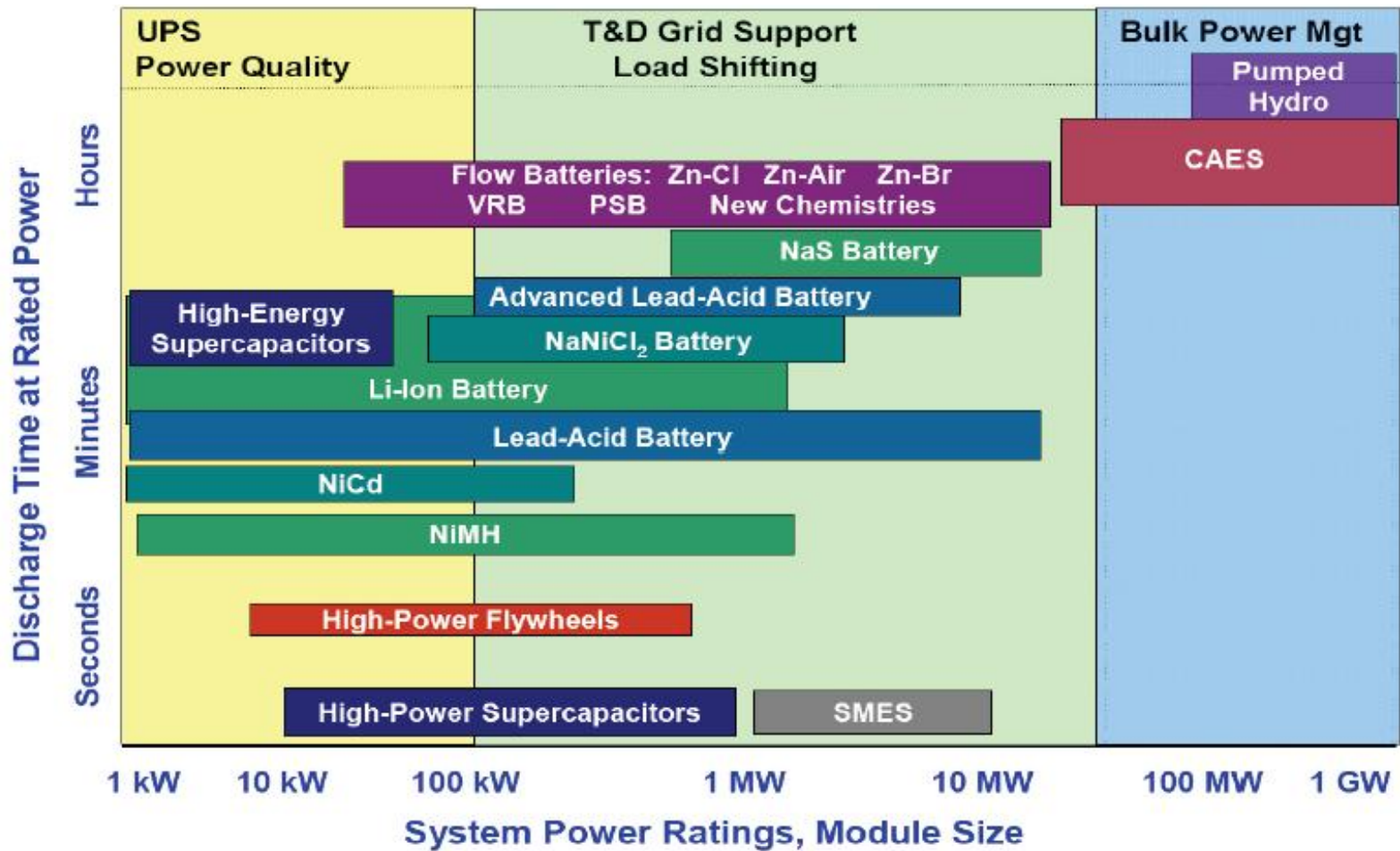
With permission from EPRI, Electric Energy Storage Technology Options: A Primer on Applications, Costs & Benefits, December 2010

Grid Energy Storage Application



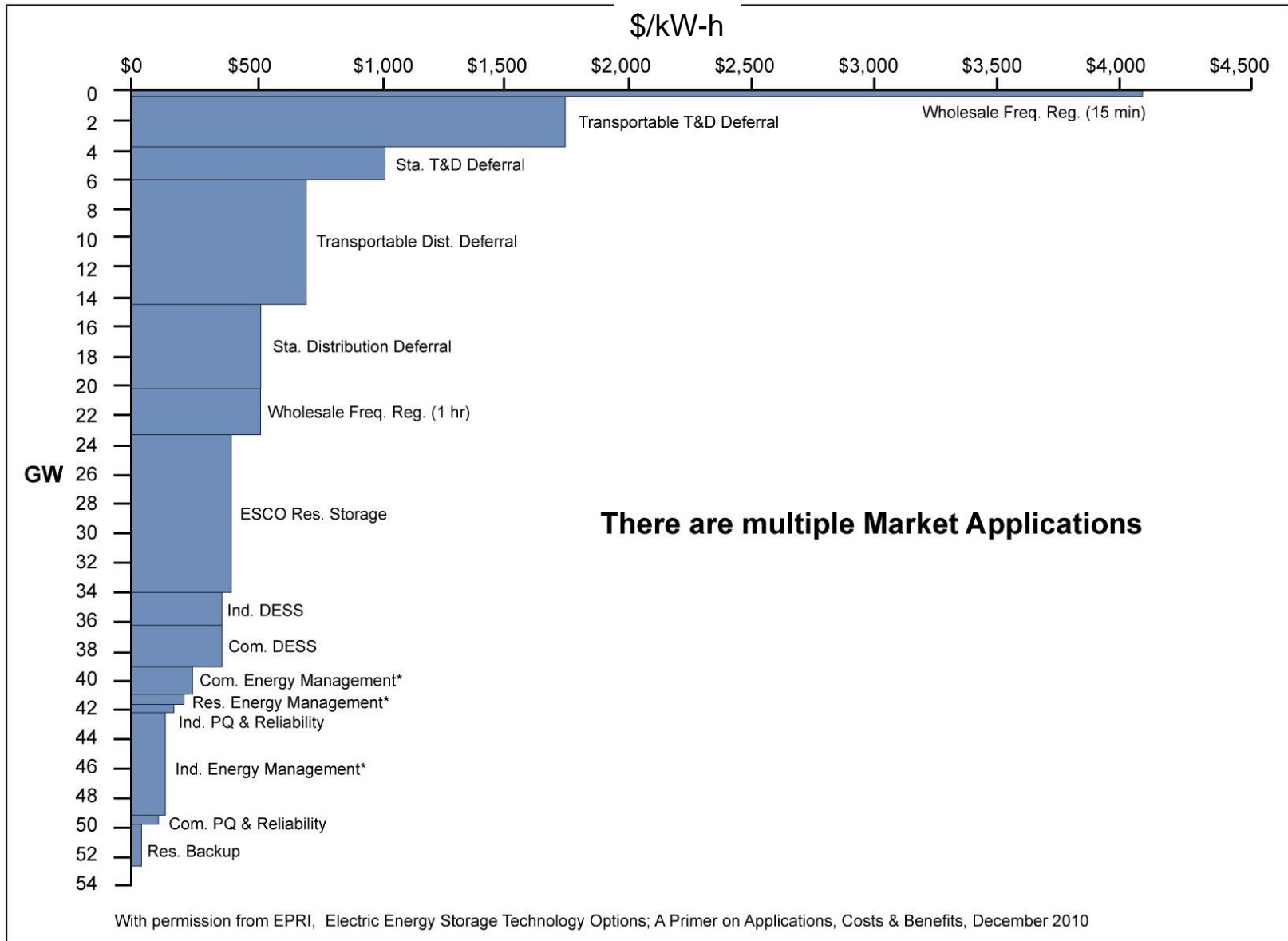
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Energy Storage Options

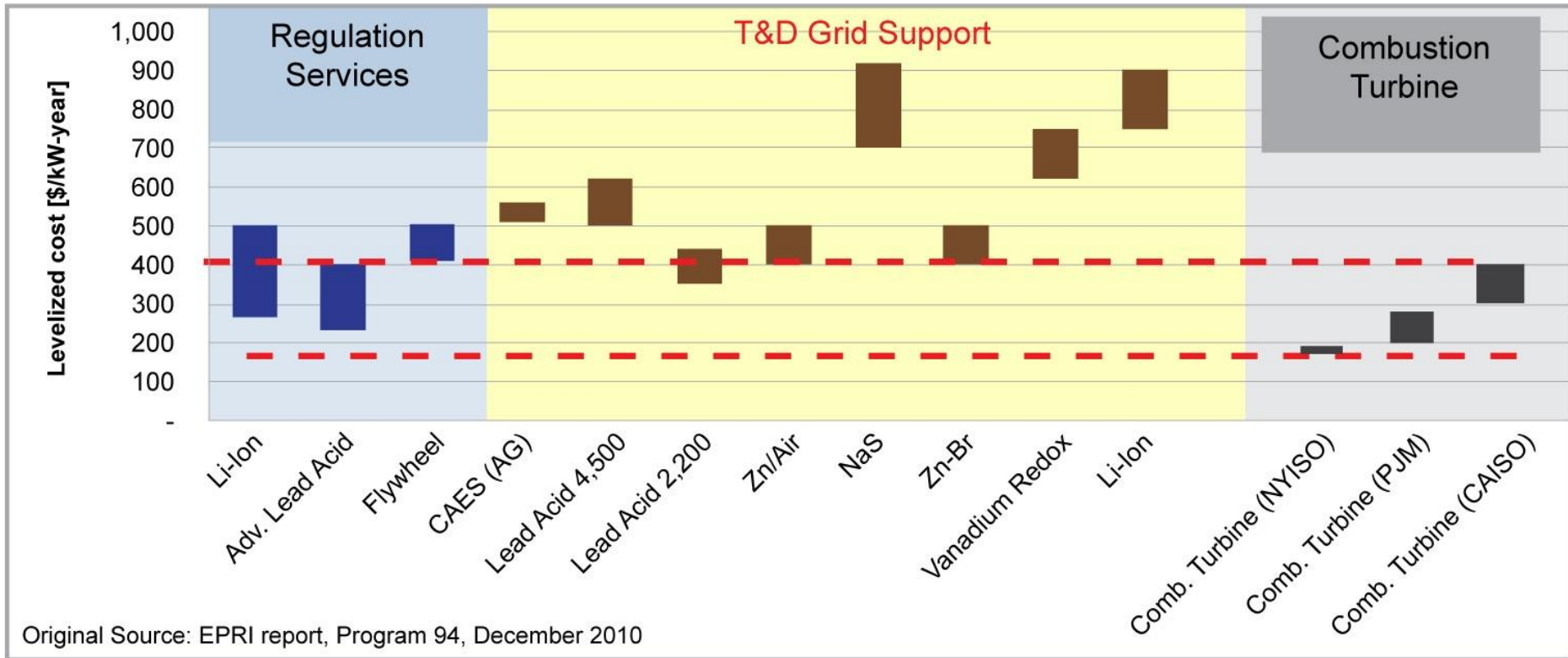


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Target Market Size and Value Analysis



Levelized Total Cost of Energy Storage Technologies Relative to Combustion Turbine



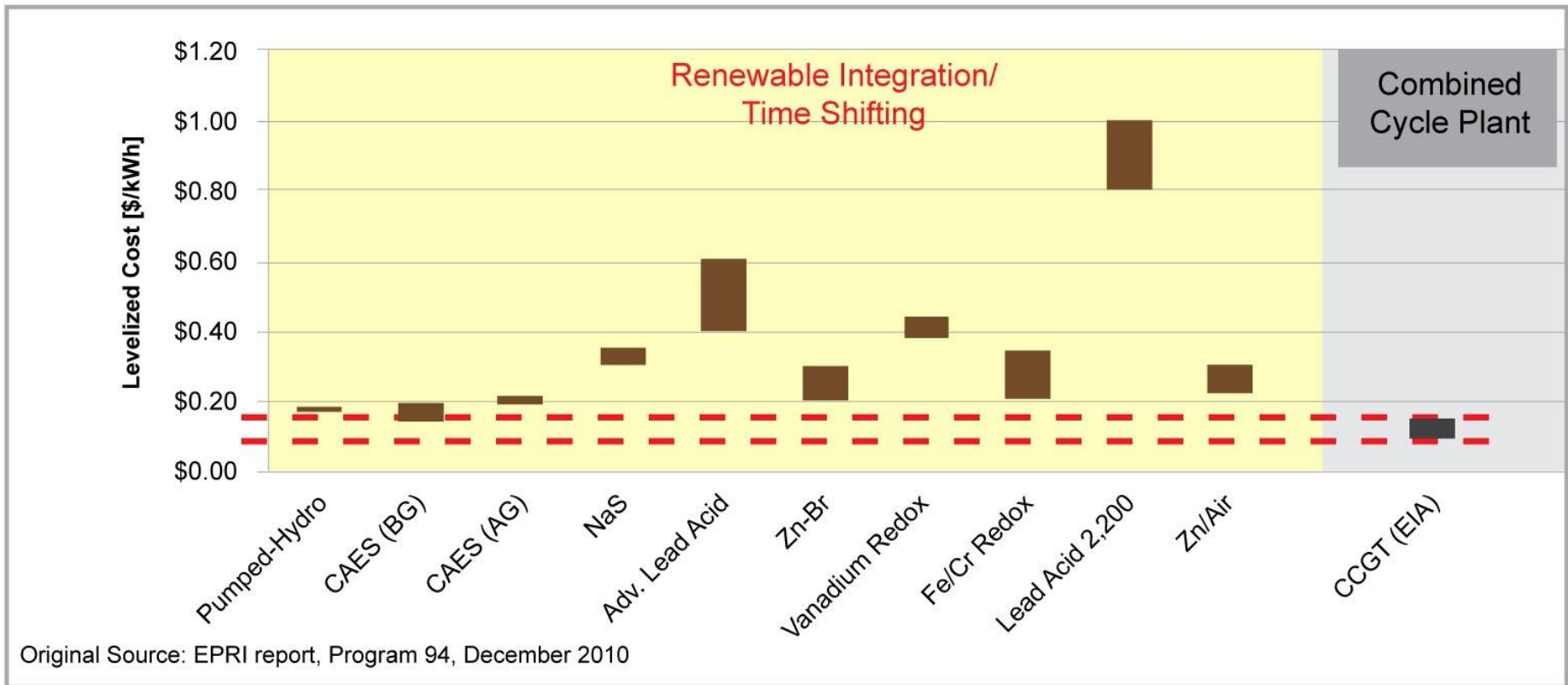
- **Some storage technologies are beginning to become competitive in selected Regulation Markets**
- **Cost of many technologies still too high!!!!!!**



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Levelized Total Cost of Energy Storage Technologies Relative to Combustion Turbine



➤ Storage (levelized) costs of energy products >2~3 times higher, for broad market penetration

ARRA Funded Demonstration Projects

\$185 M DOE Funded



Portfolio of DOE ARPA-E Projects

UNIVERSITY/ LAB



Rechargeable
Fe-Air Battery



Advanced
Flow Battery



Rechargeable
Zn-MnO₂ Battery

SMALL BUSINESS



New Flow
Battery Electrode



High Power
Metal-air Storage



Neutral Water
Fuel Cell



Long Duration
Flywheel



Fuel-Free Isothermal
Compression

CORPORATION



Advanced
Flow Battery



Soluble Lead
Flow Battery



2G-HTS
SMES



High-Energy
Flywheel

Focus: Transformational approaches to energy storage to enable low cost

< 100/kW and < 100kW-h

Grid Energy Storage Summary

- ▶ Energy Storage Market is on the order of 14 GW if energy storage systems can be installed at about \$750/kWh
 - Still must compete against energy efficiency, demand response, CCGT
- ▶ 5GW niche markets at \$1400/kWh and multiple benefit can realized.
- ▶ High value applications include:
 - Regulation, commercial and industrial power quality and reliability
 - Stationary and transportable systems for grid support and T&D deferral
- ▶ Many Energy Storage technologies are too expensive
- ▶ R&D needs to focus on those issues that increase performance/reduce cost (materials, lifetime, durability)



Questions?



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