

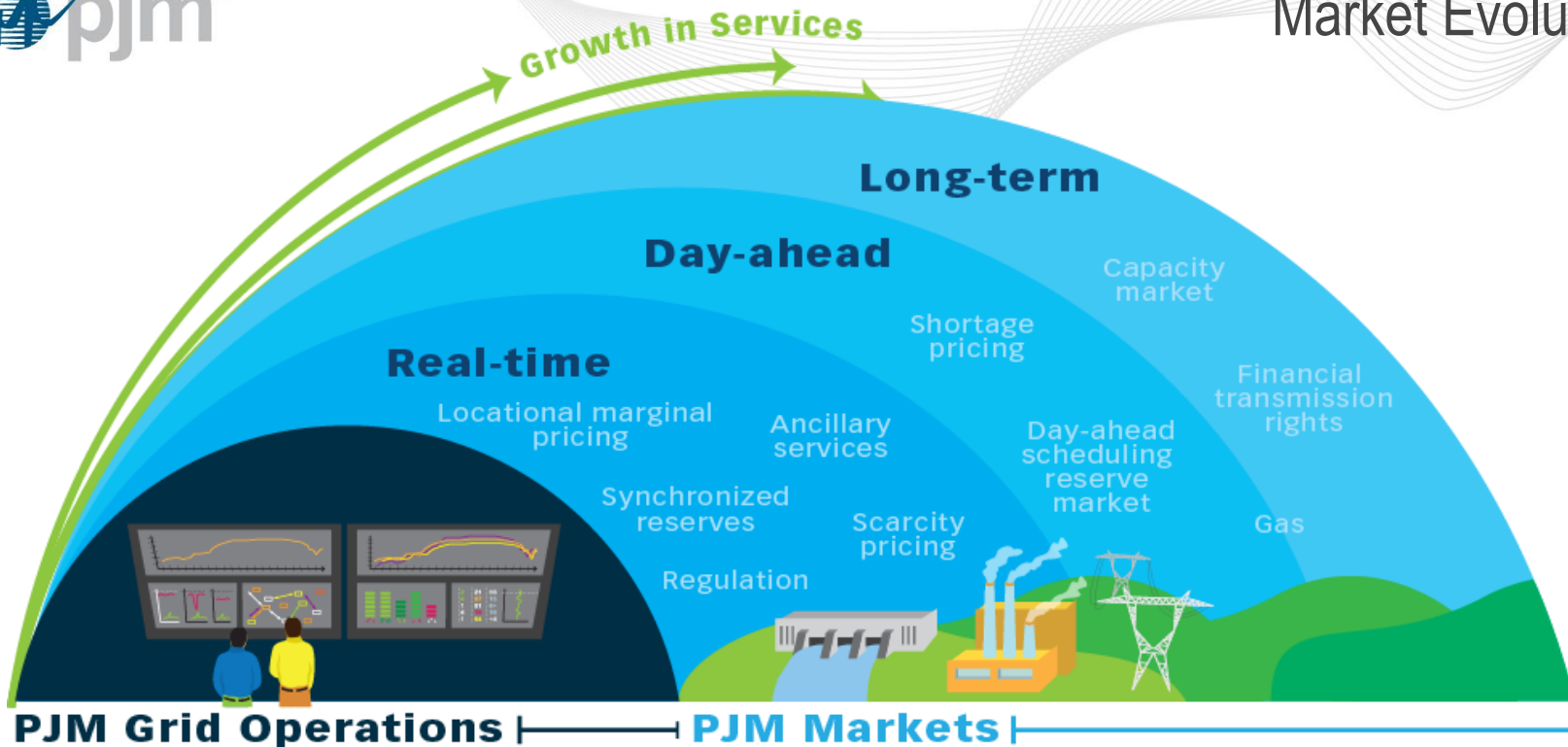
Experiences of PJM and Other US Markets in a Deregulated Environment

What has worked and what are the challenges?

Andrew Ott

Executive Vice President, Markets, PJM

May 27, 2014



- Day-Ahead Energy Market
- Real-Time Energy Market
- Capacity Market
- Financial Transmission Rights Auctions
- Gas/Electric Market Coordination

Ancillary Services Markets

- Regulation
- Synchronized Reserves
- Day-Ahead Scheduling Reserves
- Black Start Services
- Reactive Services

Successes

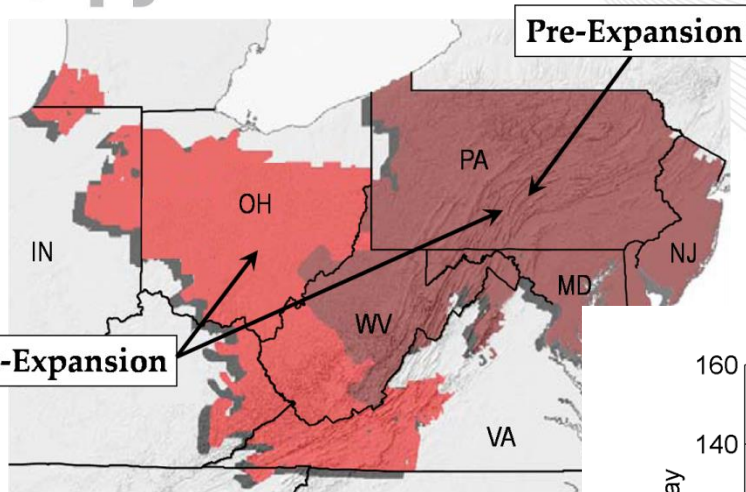
- Increased Operational Efficiency / Congestion Management
- Increased Competition
- Efficient Entry and Exit
- Promoting Innovation
- Capacity Market (PJM)
- Demand Response / Alternative Resources

Challenges

- Transmission Cost Allocation
- Resource Adequacy
- Gas/Electric Market Coordination
- Market Boundary Issues

PJM Market Expansion – A Case Study

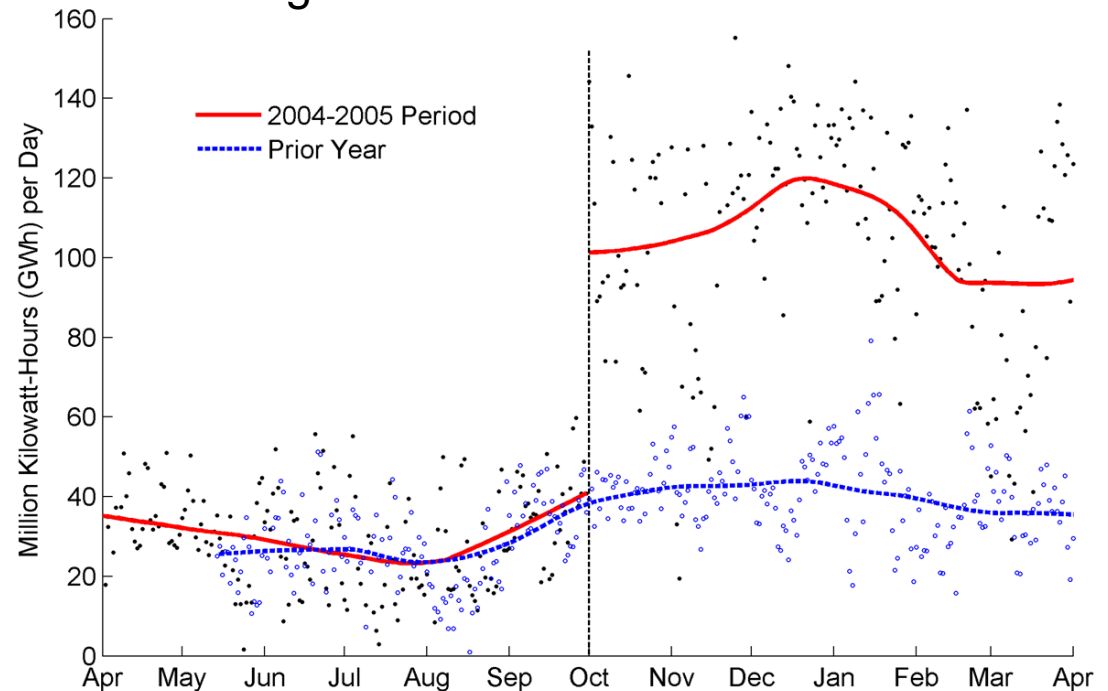
AEP / Dayton / Commonwealth Edison
Integration into the PJM Market



Key Study Conclusions:

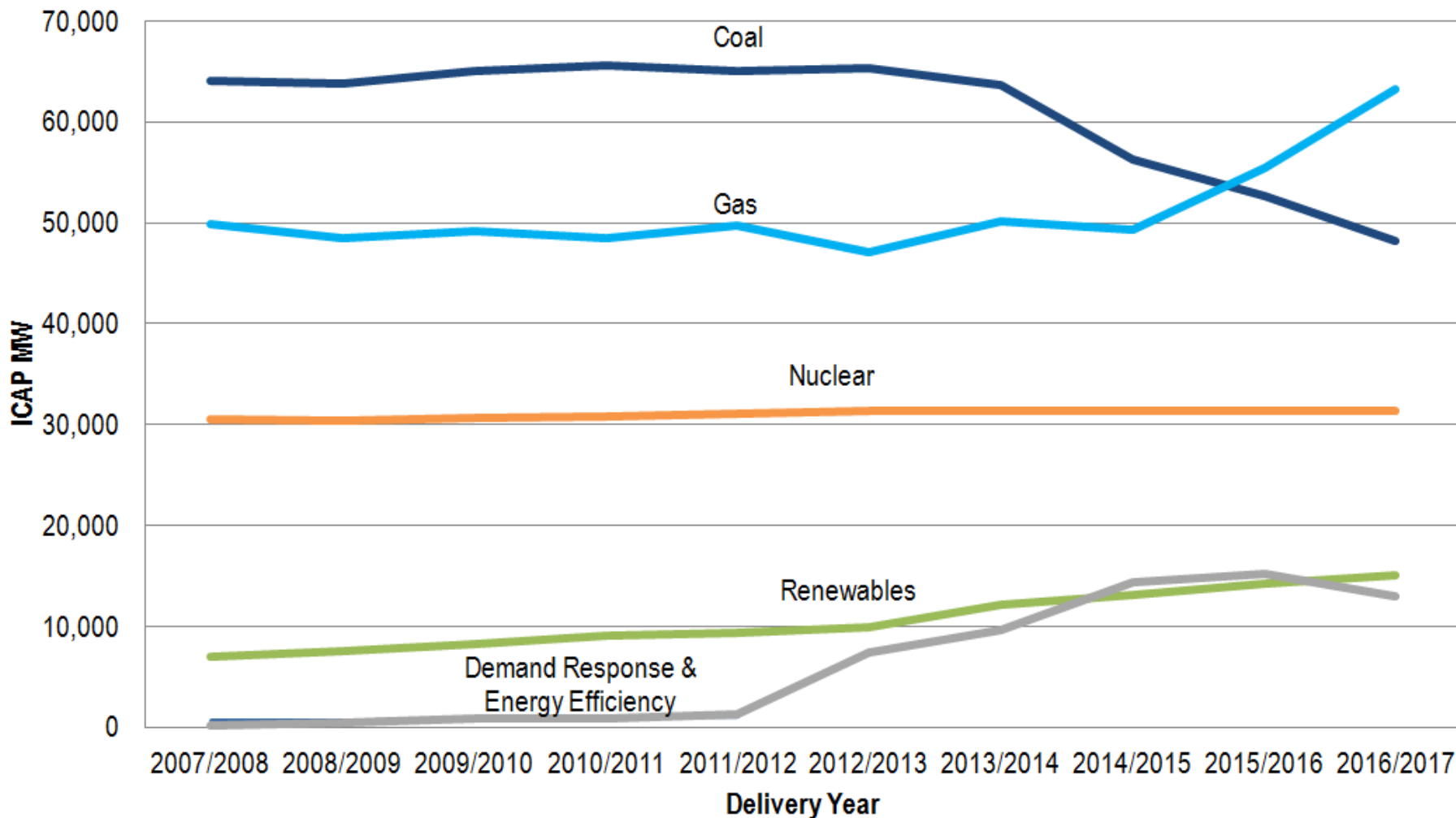
- Bilateral Trading could only achieve 40% of the efficiency gains of LMP-based market
- Incremental benefit of LMP Market Integration = \$180 Million annually, Net Present Value over 20 yrs is \$1.5 Billion

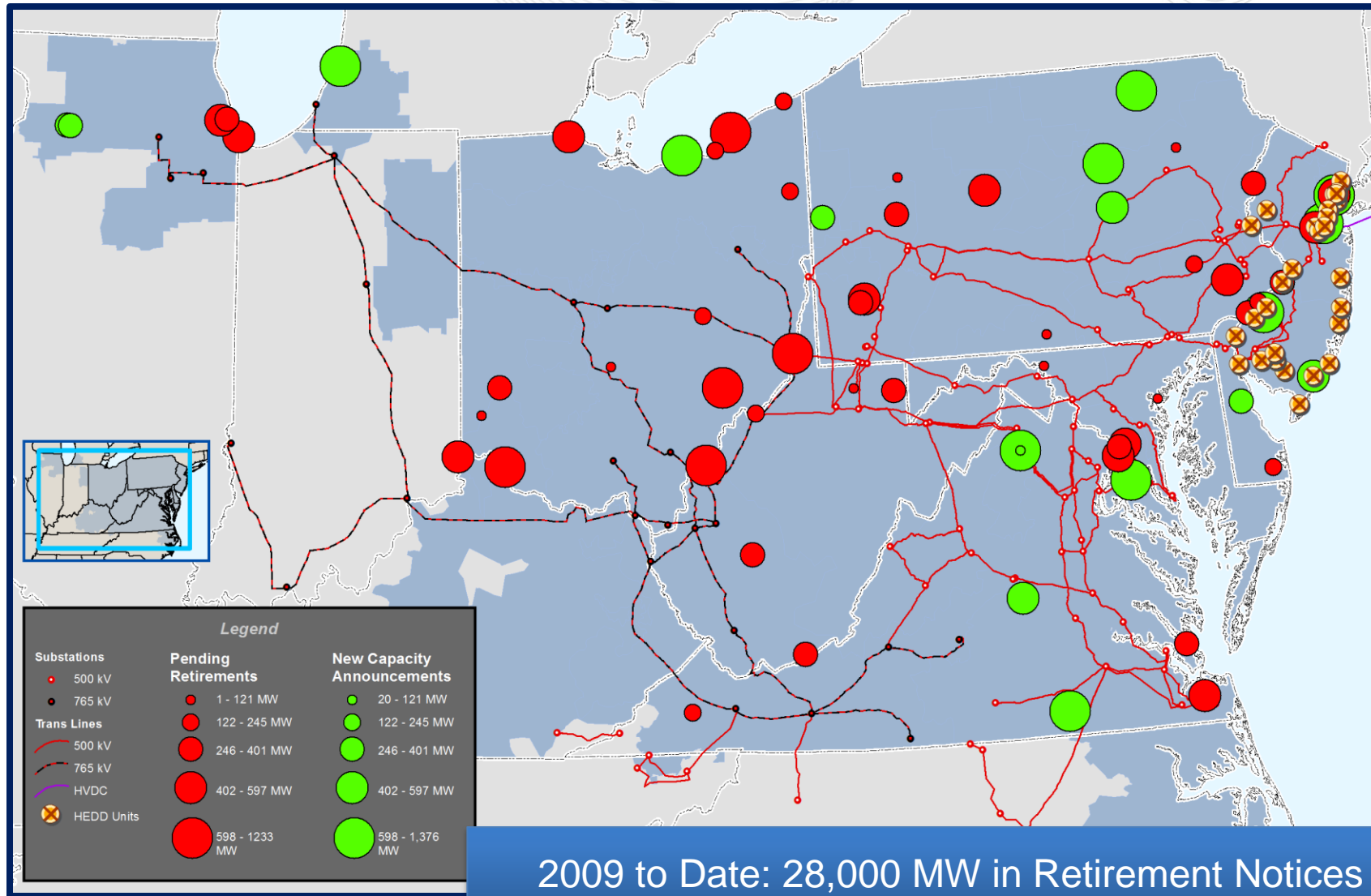
Change in Transmission Interconnector flows



Referenced with Permission: Source: Erin T. Mansur and Matthew W. White, "Market Organization and Efficiency in Electricity Markets," March 31, 2009, Figure 2, pg 50, discussion draft.

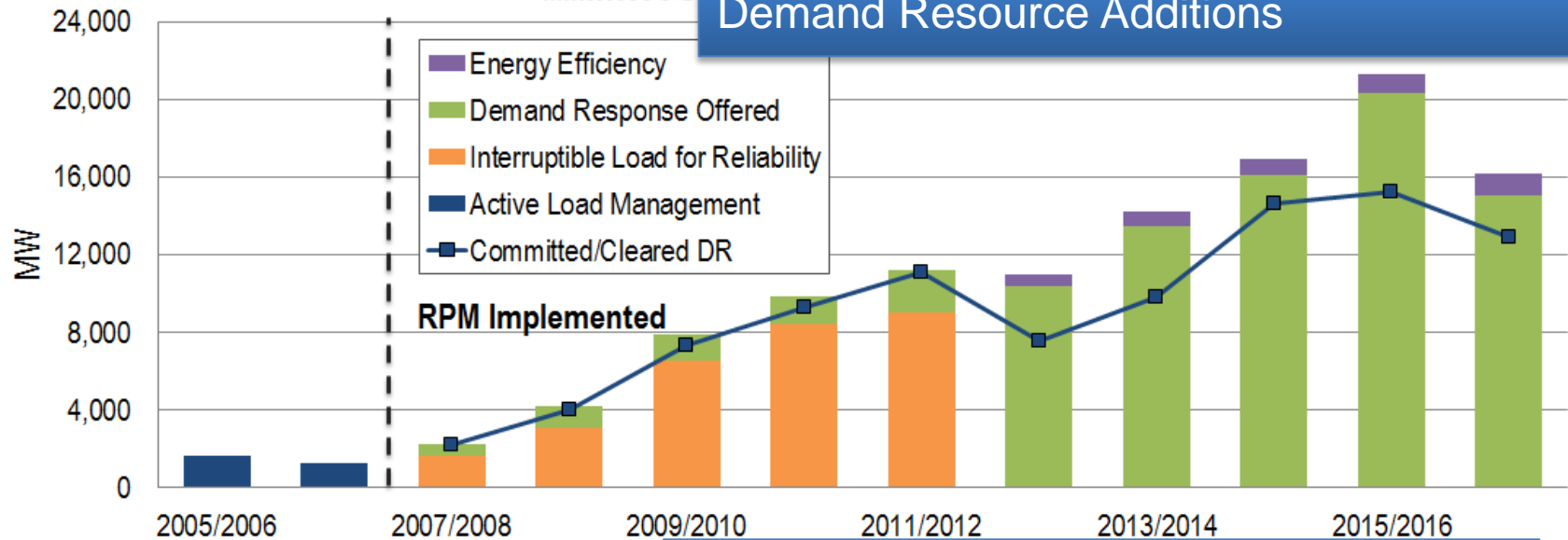
Cleared Installed Capacity



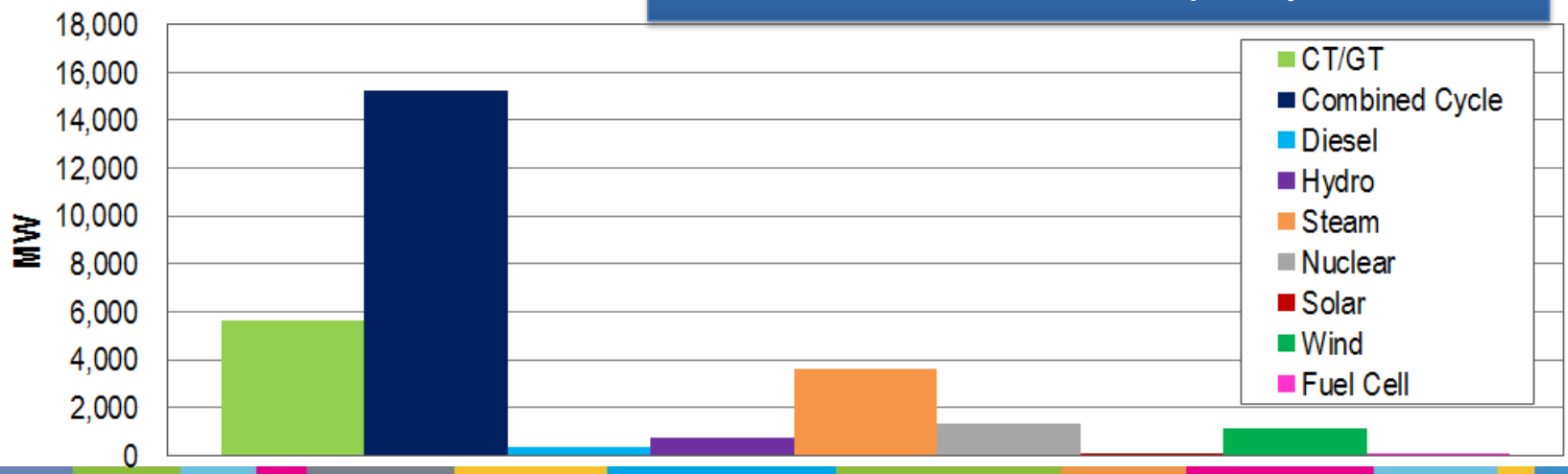


PJM Forward Capacity Market, 2007-2015

Demand Resource Additions

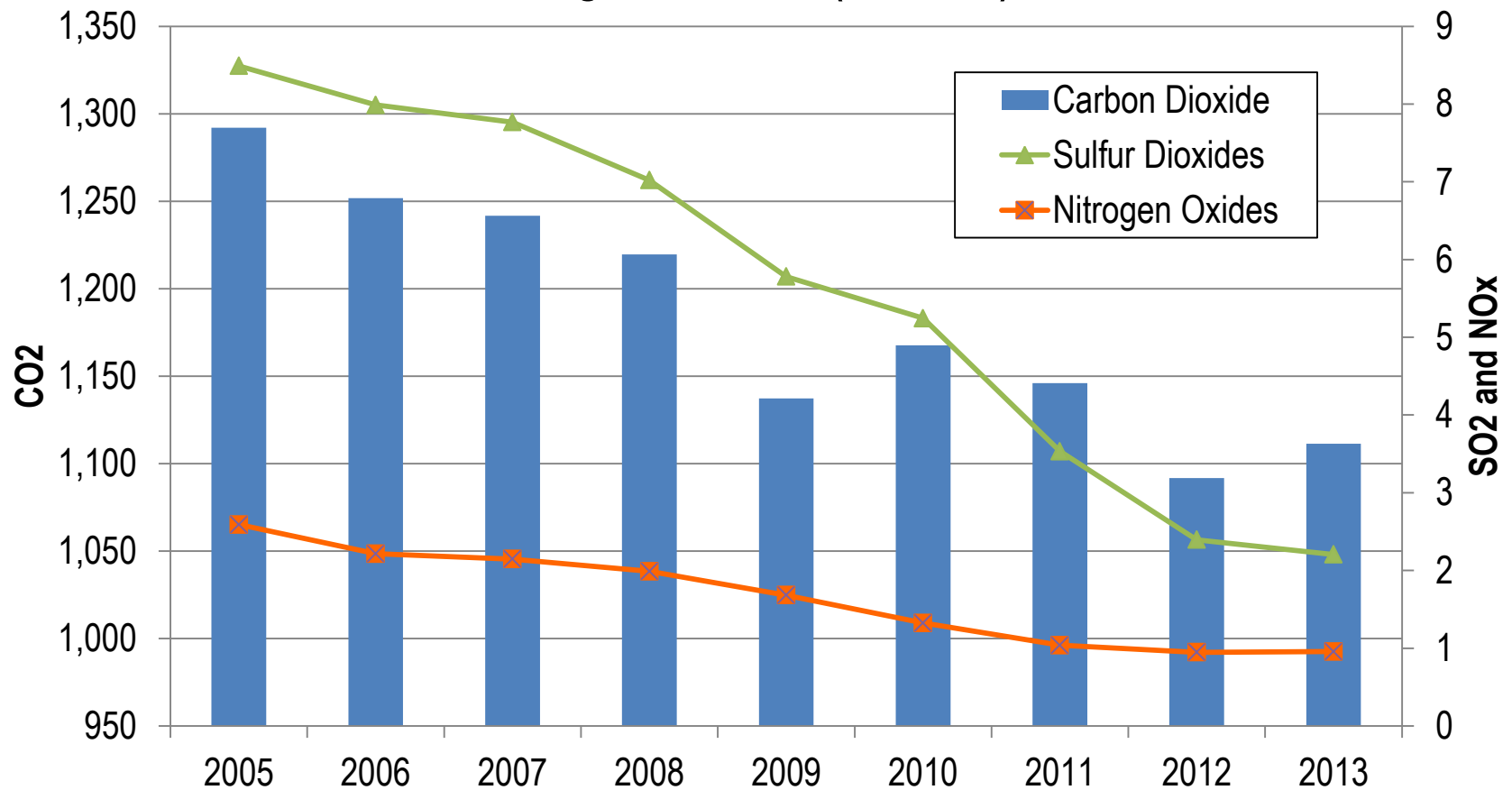


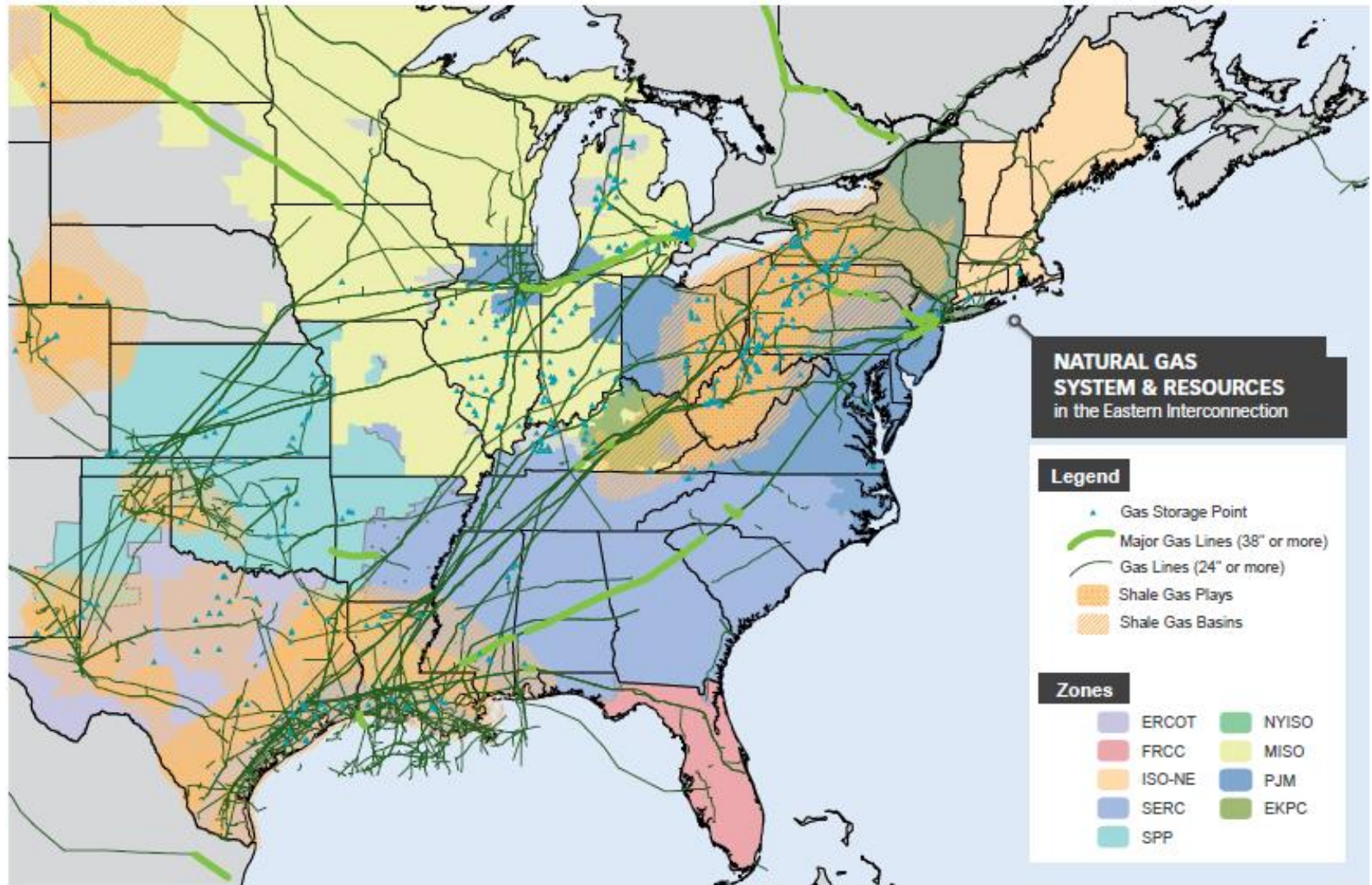
Cumulative Generator Capacity Additions



PJM Market – Average Power Generation Emissions Pounds Per MWh of Electricity Produced

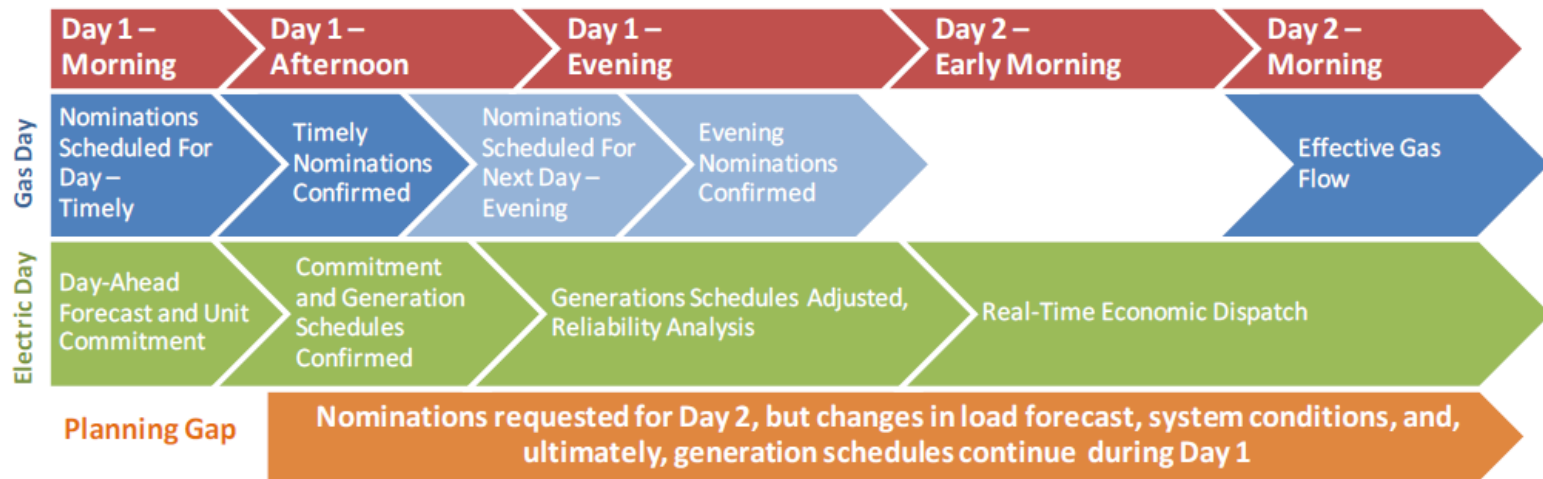
PJM Average Emissions (lbs/MWh)





Coordination Issues 1 and 2: Timing of Offers and Nominations and Clearing

FIGURE 7-9: SIMPLIFIED GAS AND ELECTRIC PLANNING AND OPERATIONS DAYS



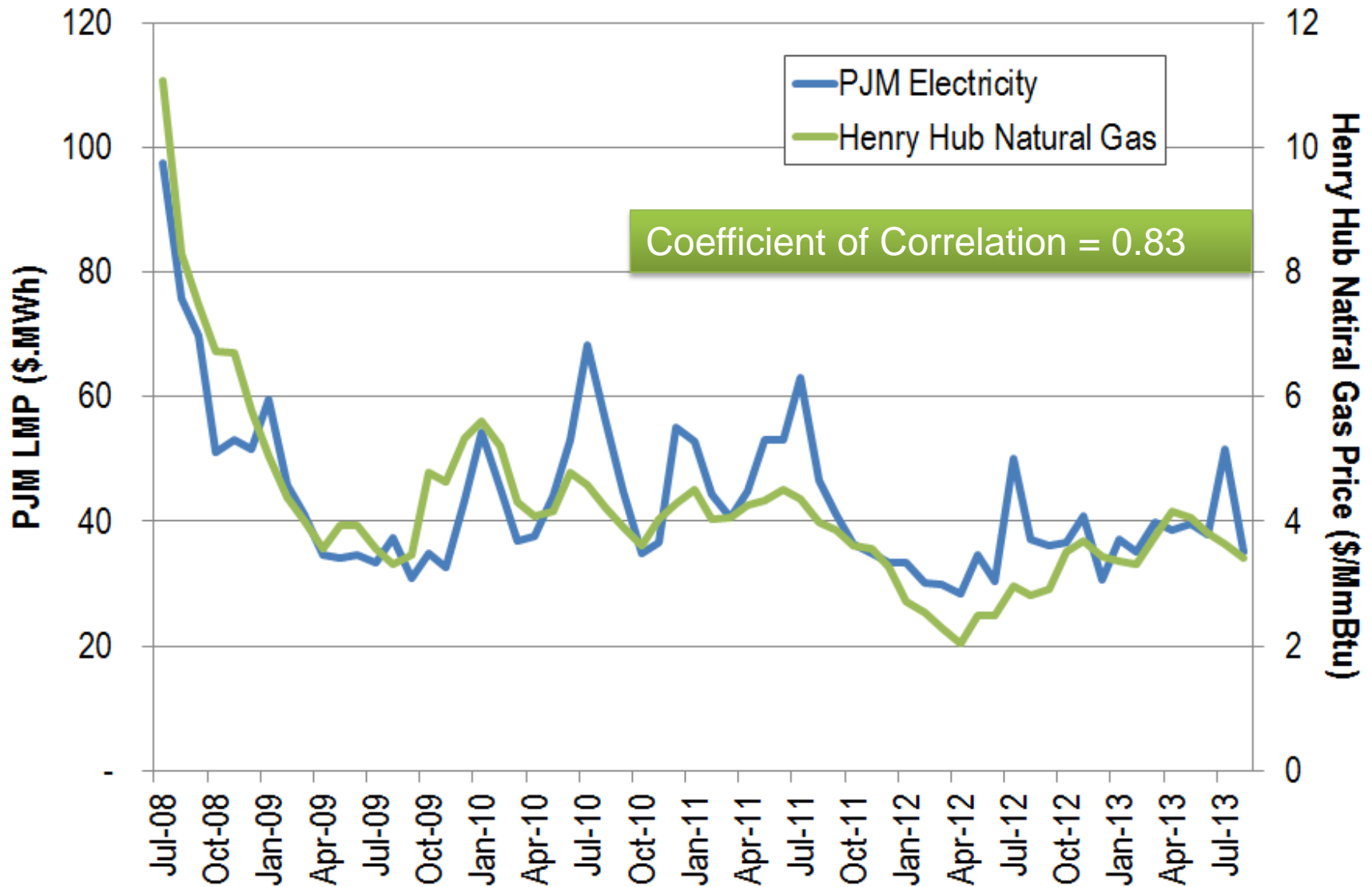
Issue:

Timely gas nominations are due at **12:30pm EPT** the day before (Day 1).

Electric “awards” are made at **4pm EPT** the day before (Day 1) **3.5 hours later**; actual gas flow occurs starting at 10am EPT on Day 2

Source: NERC report on Gas Electric Interdependency

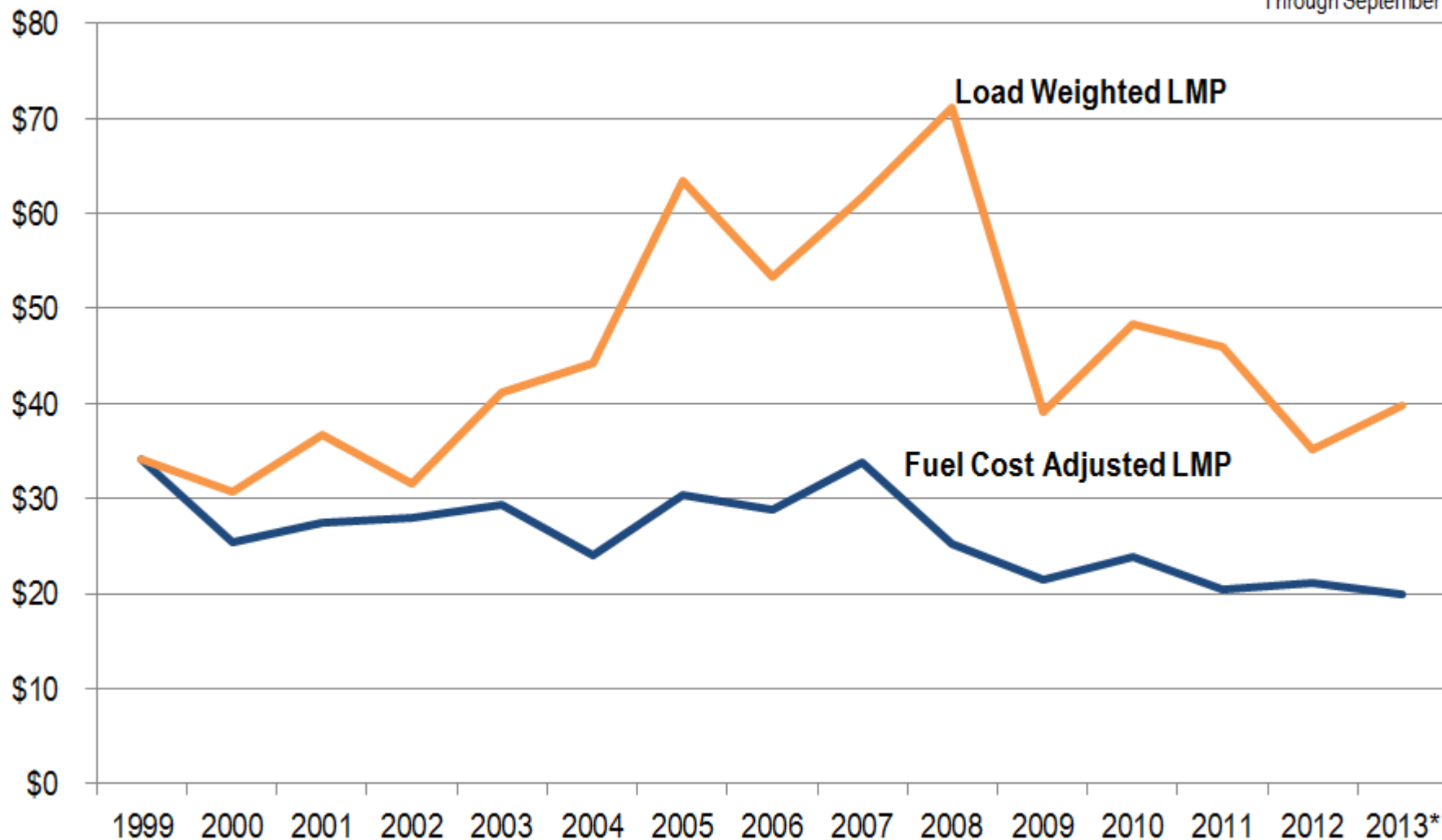
PJM LMP vs. Henry Hub Natural Gas Price



Fuel Cost Adjusted LMP

(referenced to 1999 fuel prices through September 2013)

*Through September



Evolution of Supply

- Traditional resources



Less flexible

- Renewable resources



Intermittent

- Less capability to provide power grid services

Evolution of Demand

- Technology enabled flexibility
- Alternative resource growth
- Enhanced capability to provide grid services

Market Evolution

- Improvement in optimization and control systems
- More real-time markets to reward consumer flexibility
- Development of Forward Demand Response Control Signals

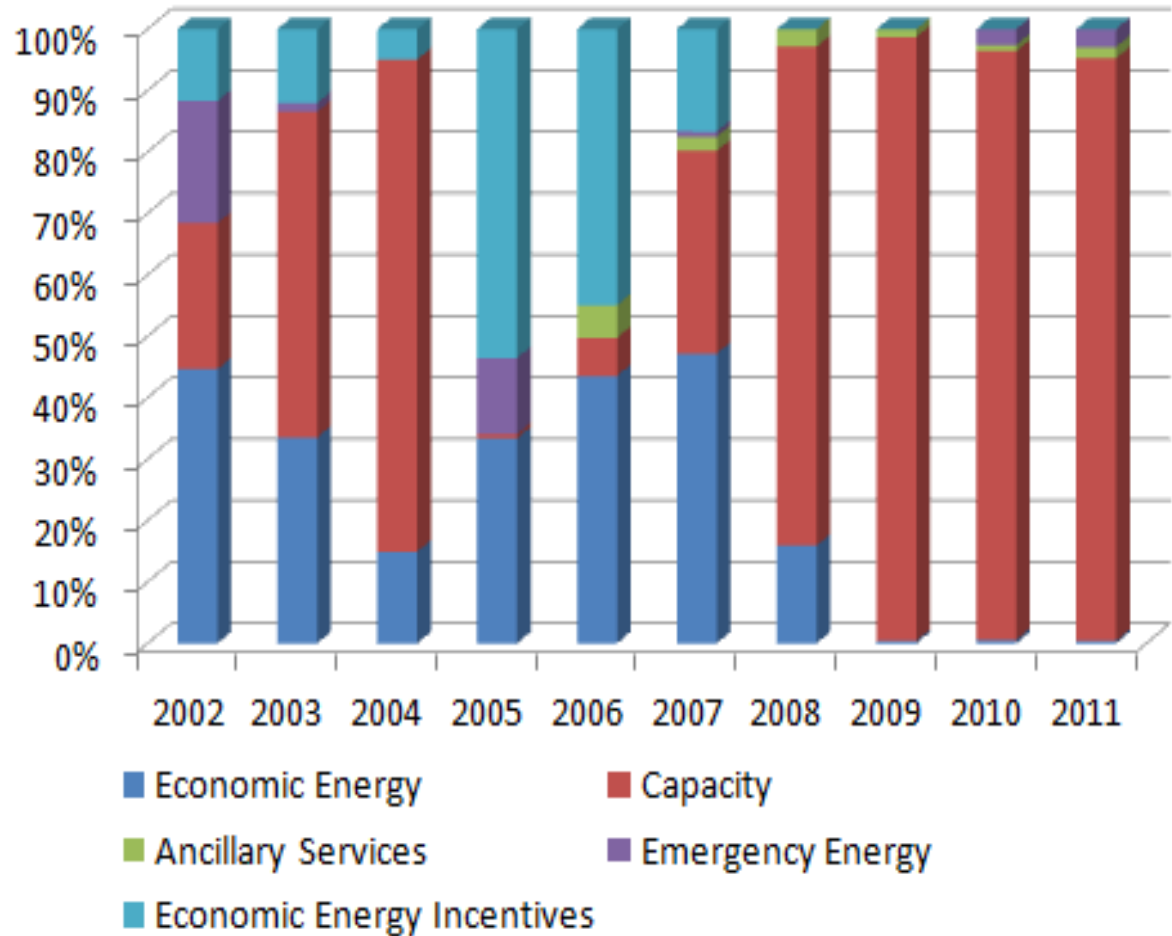


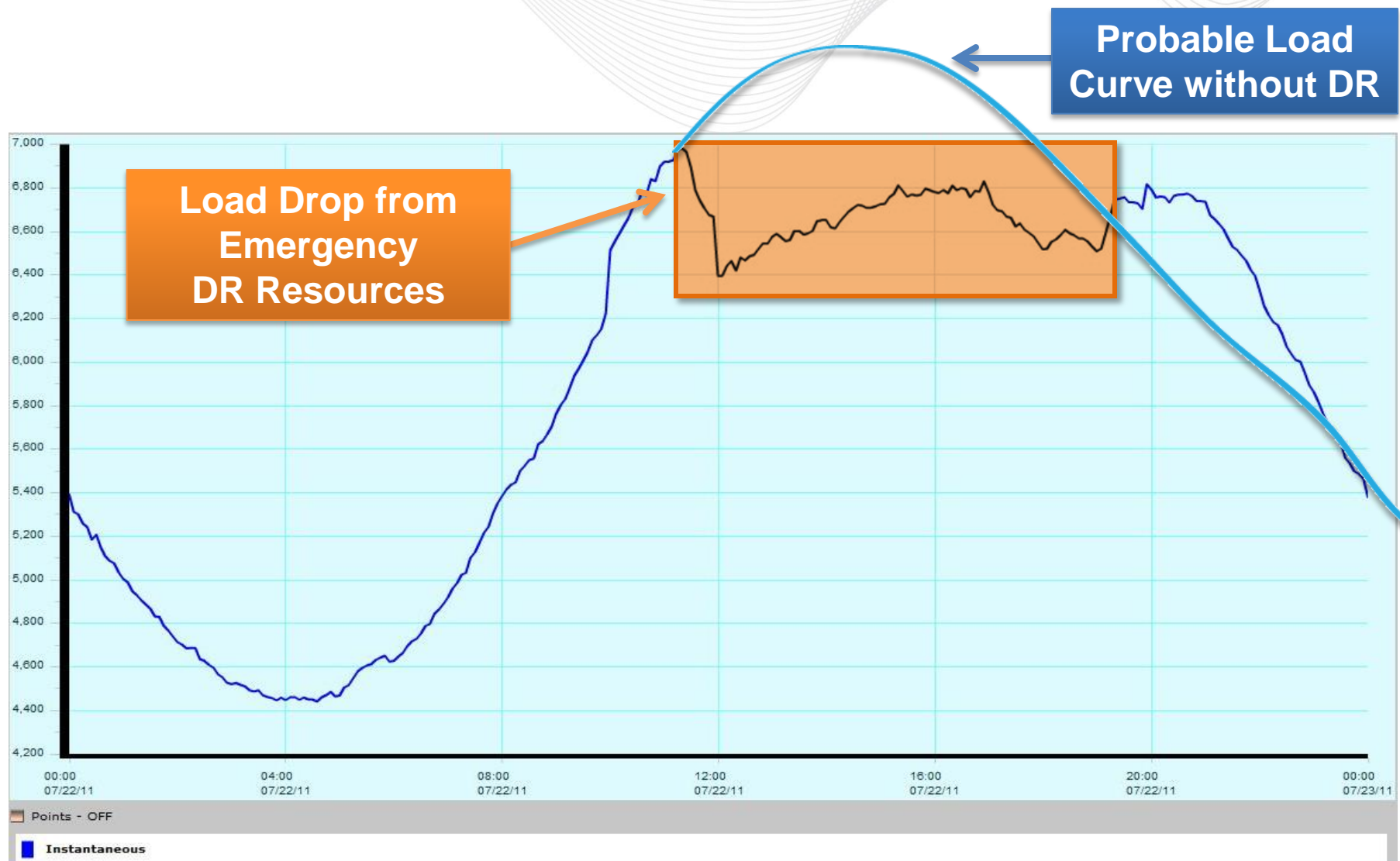
- Industry Leadership
- Customer Focused
 - eLoad Response
- Technology
 - Resource Control Application
 - Time-coupled Optimization
- Business Resiliency
 - Security
 - Dual Control Centers

- Trends
 - Increase in customer commitment to curtail demand during high price periods
 - Smart Grid Technology deployment
 - Retail rate innovation
- Operational Implications
 - Increase in customer response to price
 - Aggregated demand resources providing high quality grid services
 - Increasing operational confidence in DR performance

- Storage
 - Stationary Battery
 - Ancillary Service supply
 - Integration with intermittent resources
 - Water Heaters
 - Compressed Air
 - Electric Vehicles
- Integrated renewable resource and building management systems
- Integrated distributed resources

- Nearly 25% of synchronous reserves are provided by DR
- DR revenues grew from around \$1.4 million in 2002 to over \$1 Billion annually





Grid-Scale Energy Storage System – 32 MW Battery

Laurel Mountain

Wind Farm

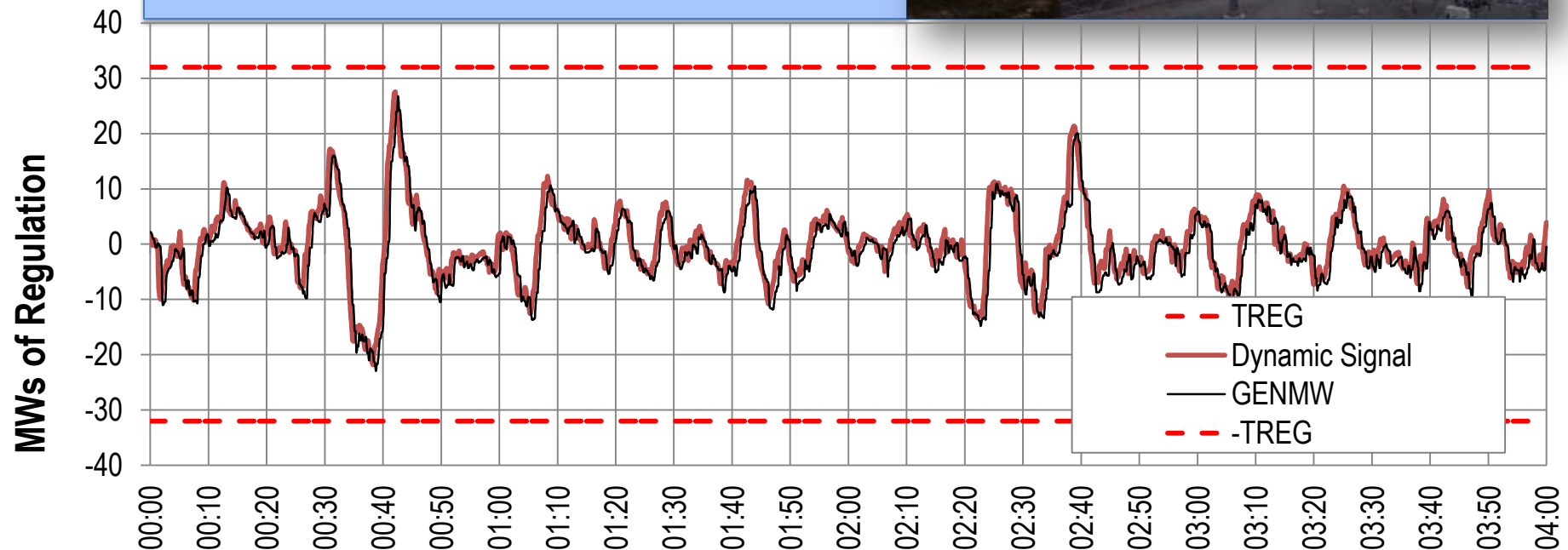
98 MW

61 turbines

Battery Storage

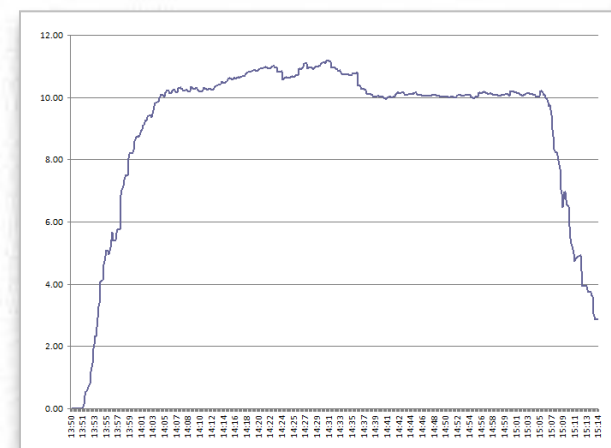
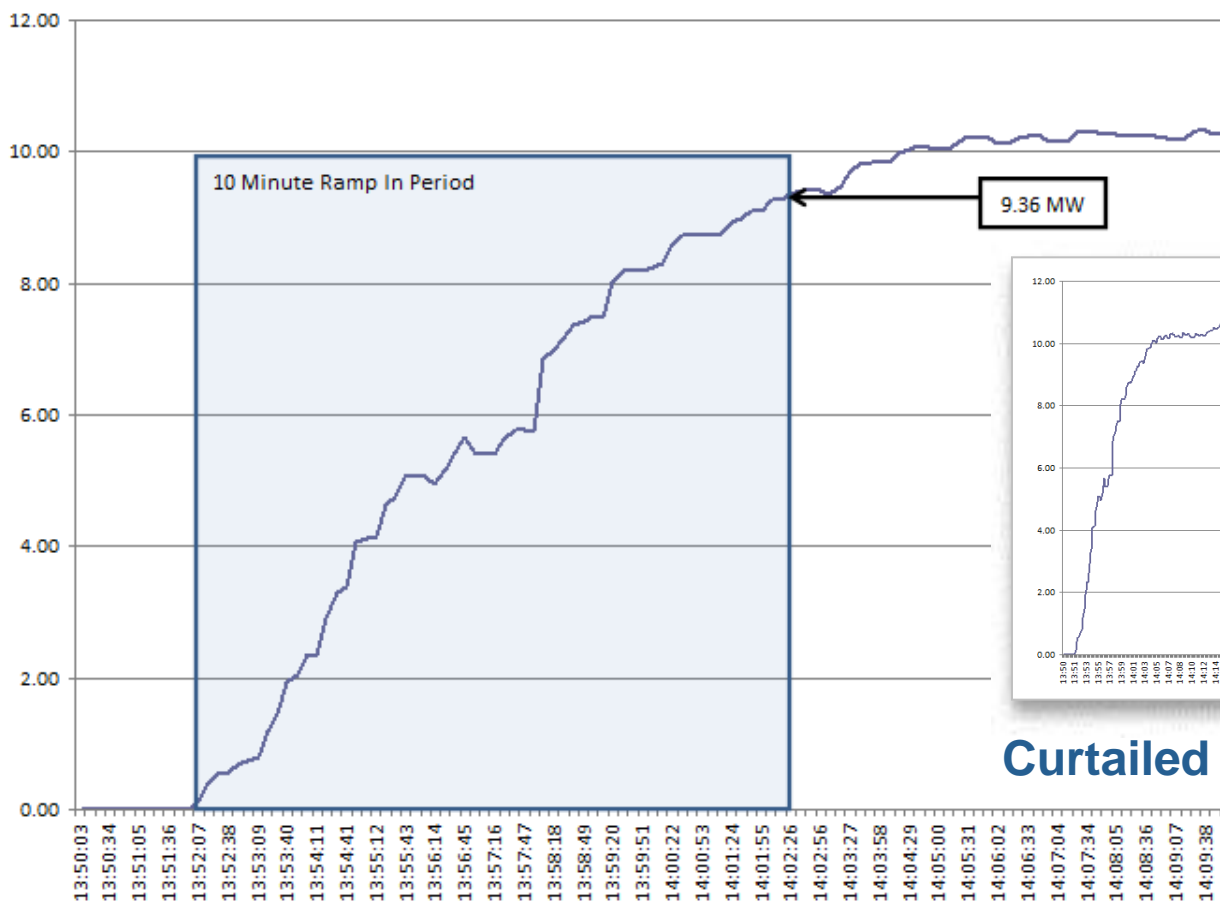
Lithium-ion (A123)

Power 32 MW, Energy 8 MWh



Aggregation 13,078 Residential Customers

Wireless Integrated
Control Platform



Curtailed Load Event graph