

Building efficient wholesale markets, the RTO/ISO model

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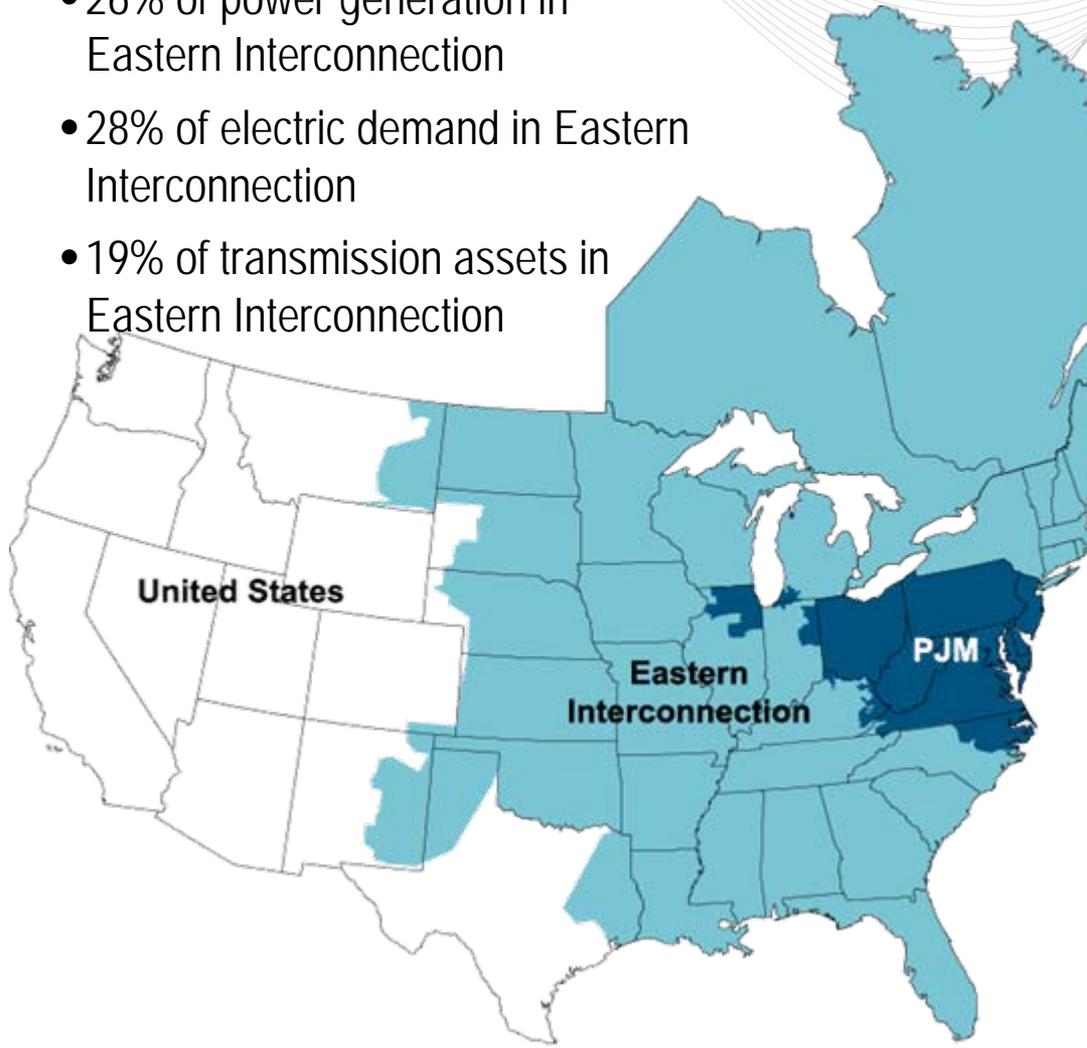
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PJM Wholesale Electric Power Market

- 26% of power generation in Eastern Interconnection
- 28% of electric demand in Eastern Interconnection
- 19% of transmission assets in Eastern Interconnection



KEY STATISTICS

PJM member companies	800
millions of people served	60
peak load in megawatts	163,848
MWs of generating capacity	185,600
miles of transmission lines	62,591
GWh of annual energy generation	832,331
sources	1,365
square miles of territory	214,000
area served	13 states + DC
Internal/external tie lines	142

**21% of U.S. GDP
produced in PJM**

As of 6/2012

Evolution of Supply

- Traditional resources



Less flexible

- Renewable resources



Intermittent

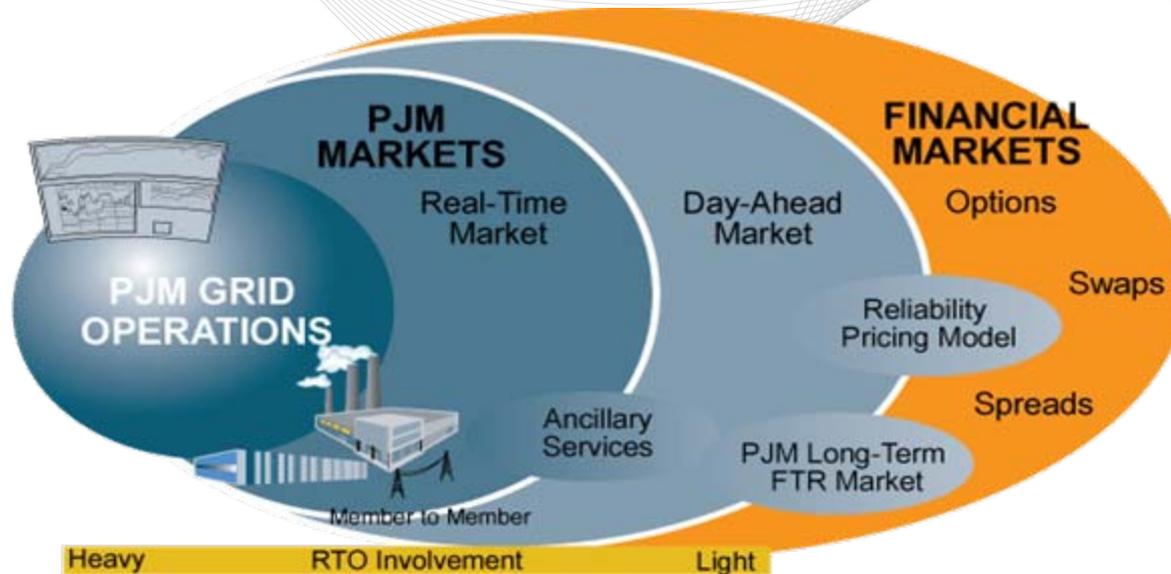
- Less capability to provide power grid services

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



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

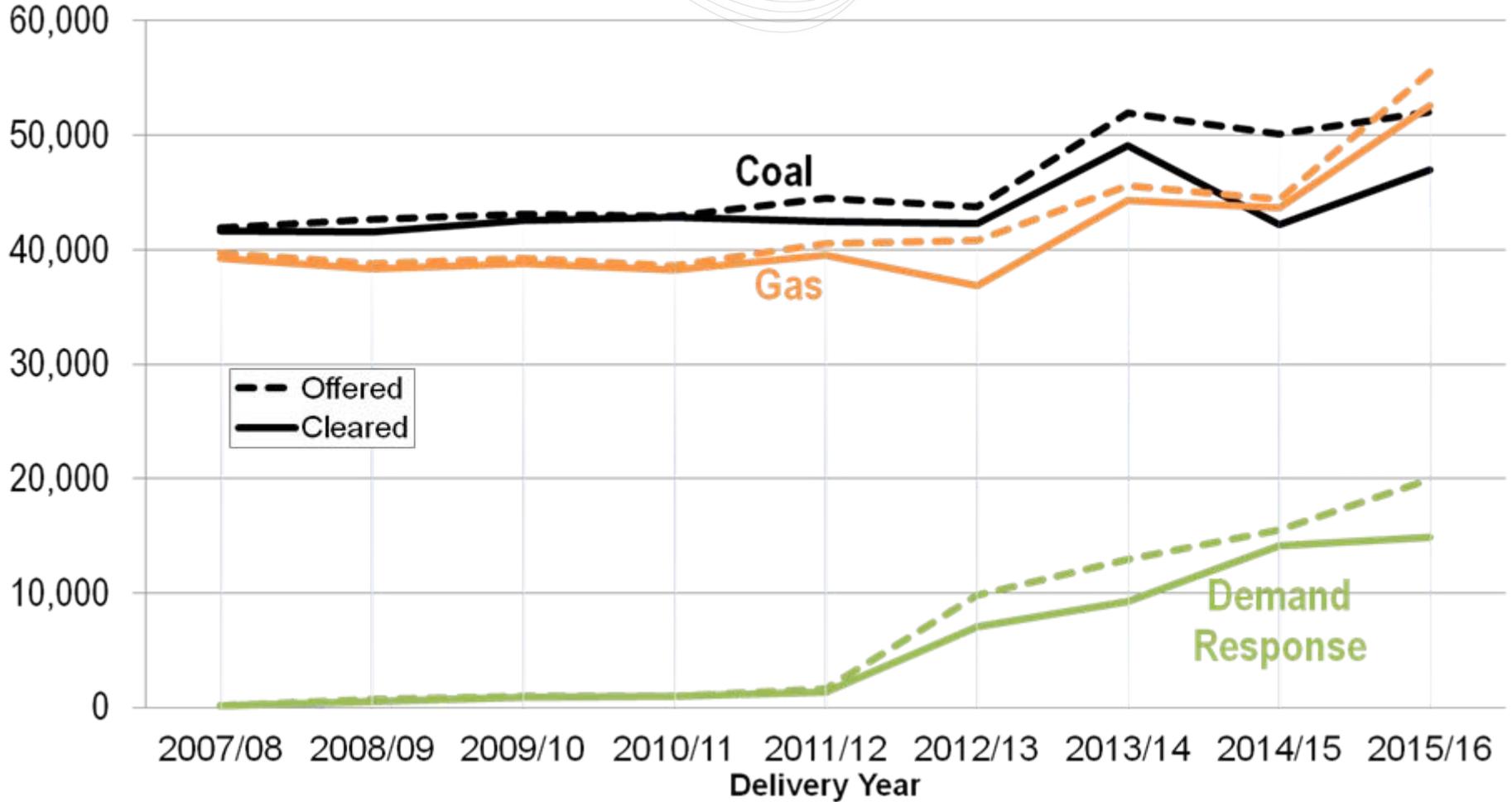
Ancillary Services Markets

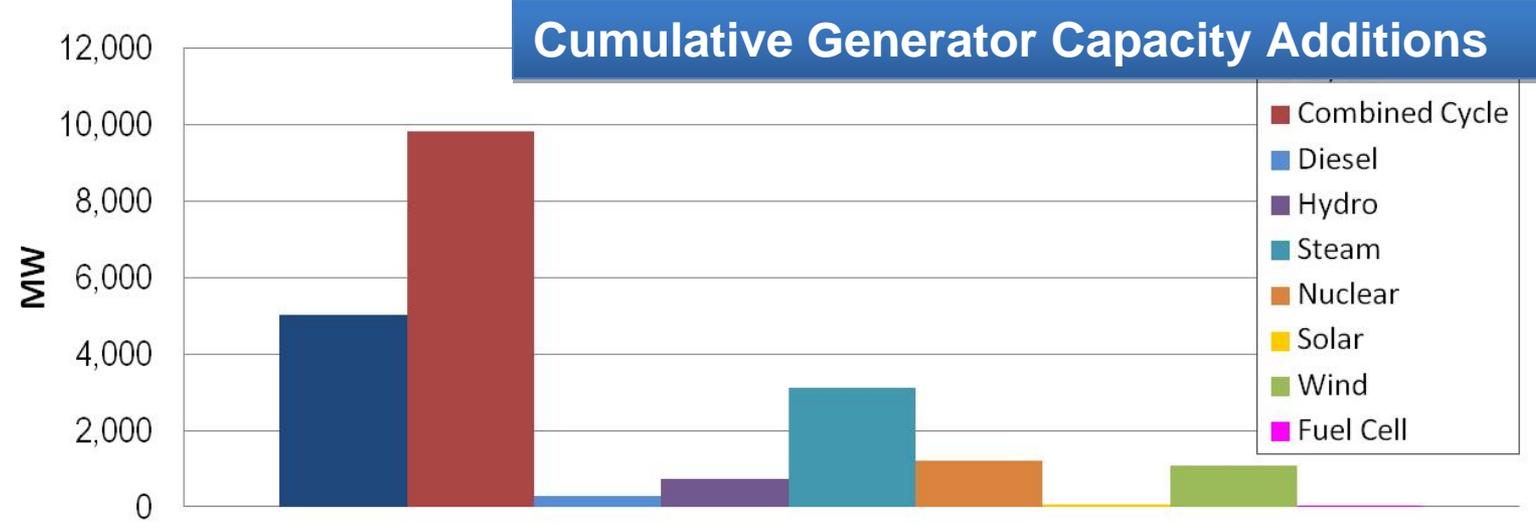
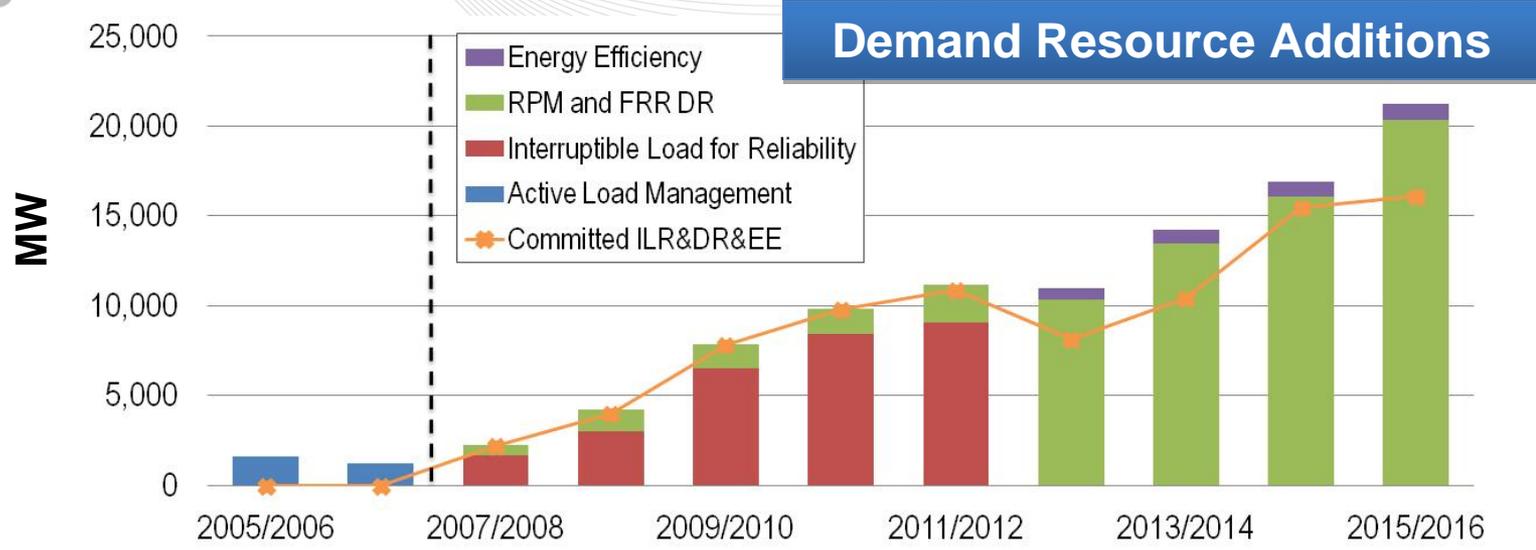
- **Regulation**
- **Synchronized Reserves**
- **Day-Ahead Scheduling Reserves**
- **Black Start Services**
- **Reactive Services**

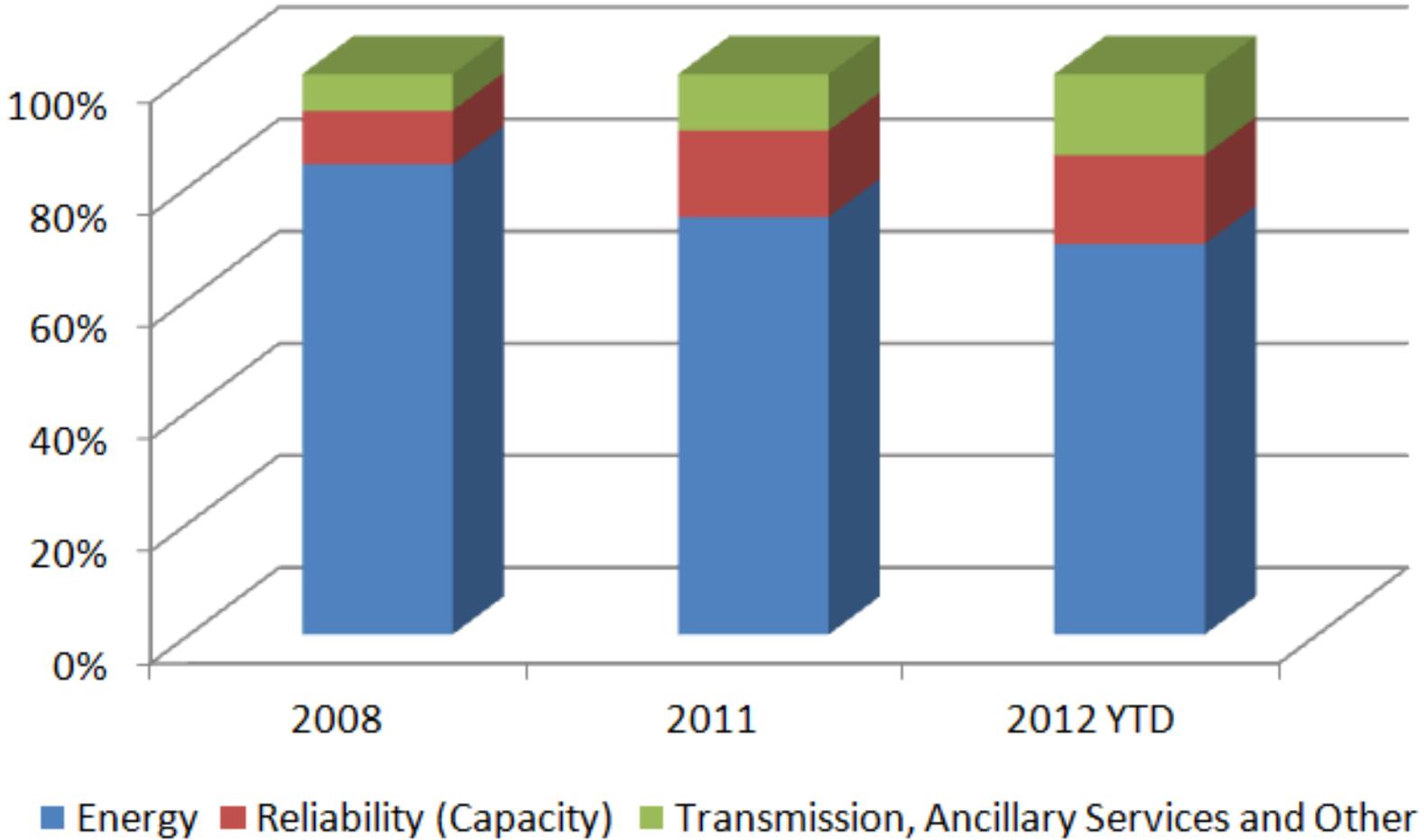


- Business Resiliency
 - Dual Control Centers
- Industry Leadership
 - Shared Architecture
- Security
 - Secure Systems
- Technology
 - Service Oriented Architecture

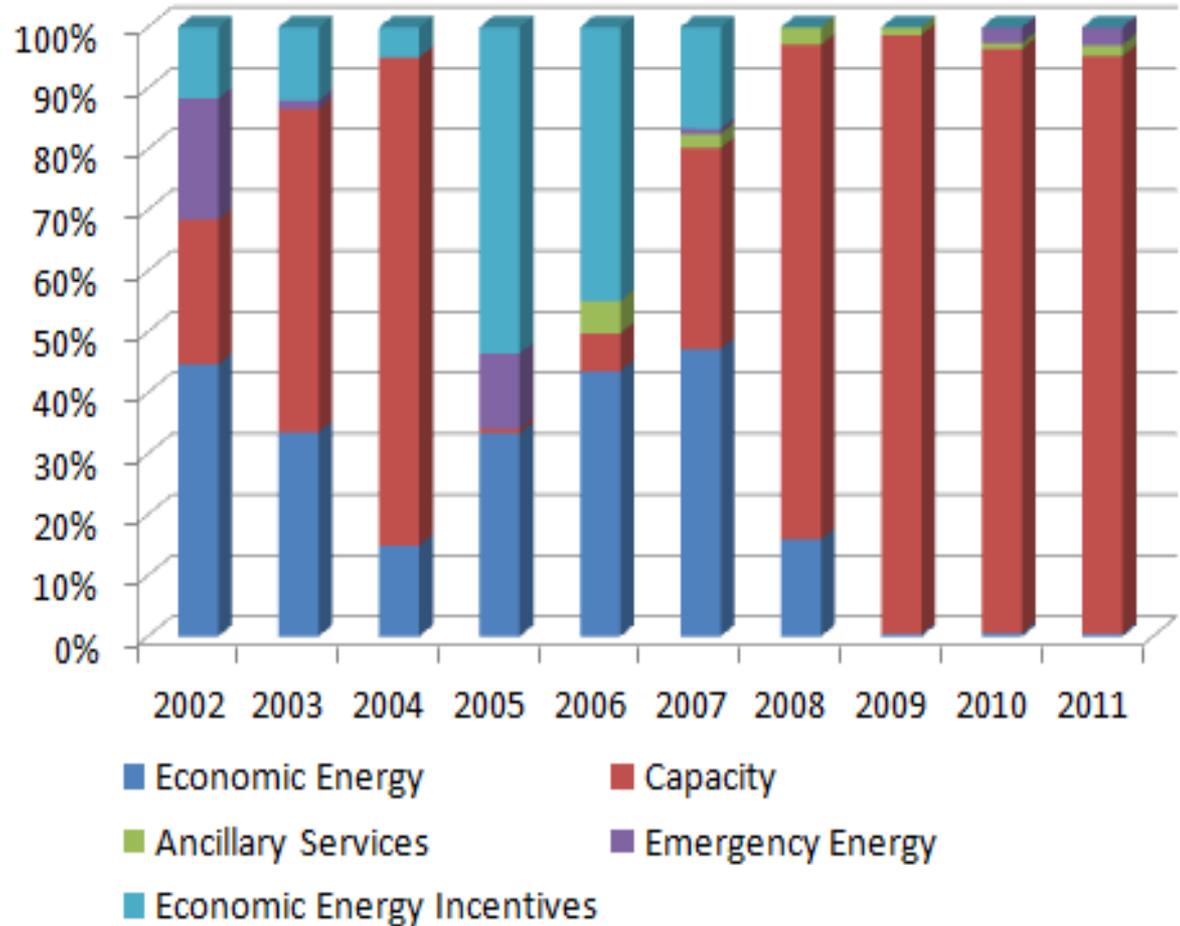
PJM Unforced Capacity Offered and Cleared MWs





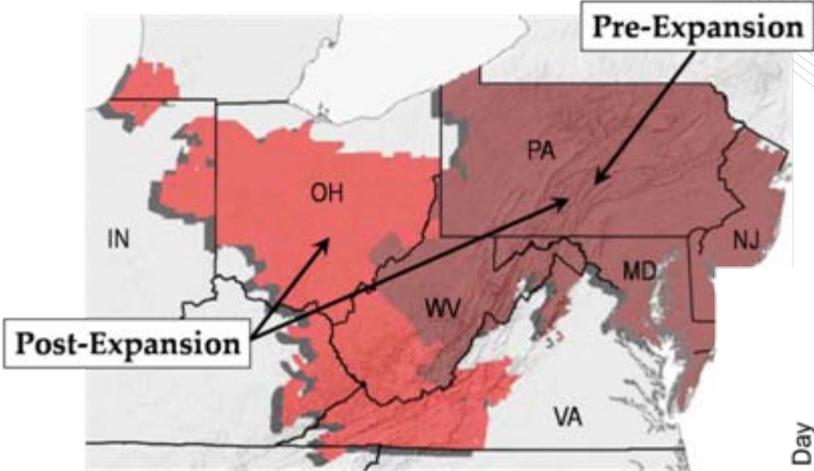


- Nearly 25% of synchronous reserves are provided by DR
- DR revenues grew from around \$1.4 million in 2002 to over \$500 million annually

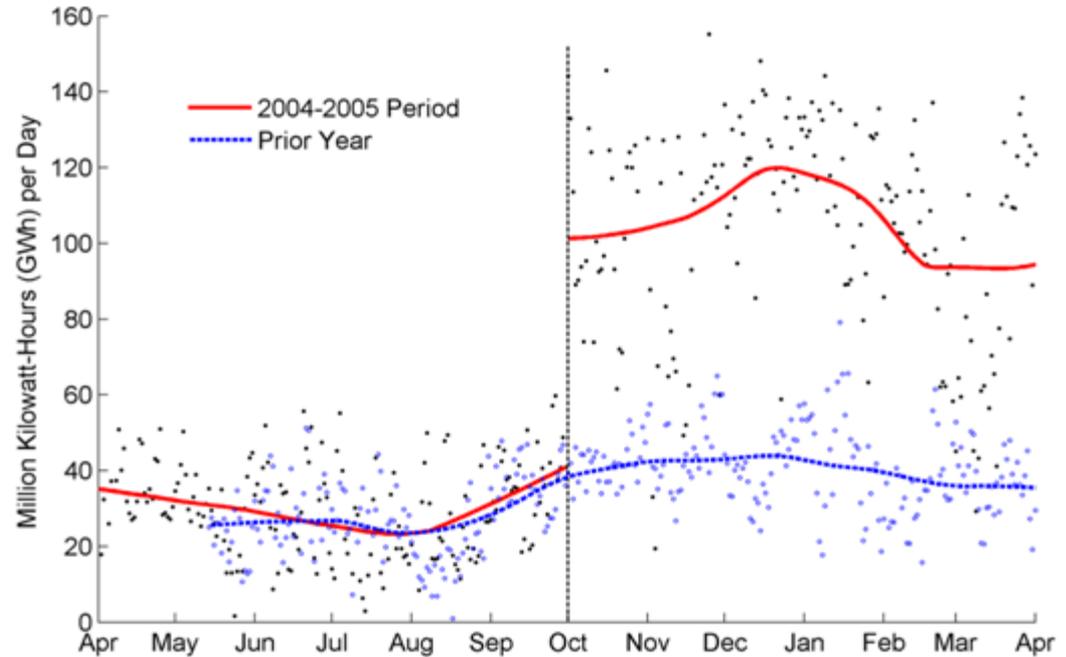


Trend toward Larger Regional Operations and Markets

AEP / Dayton / ComEd Integration into the PJM Market



Change in Transmission Interconnector flows



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

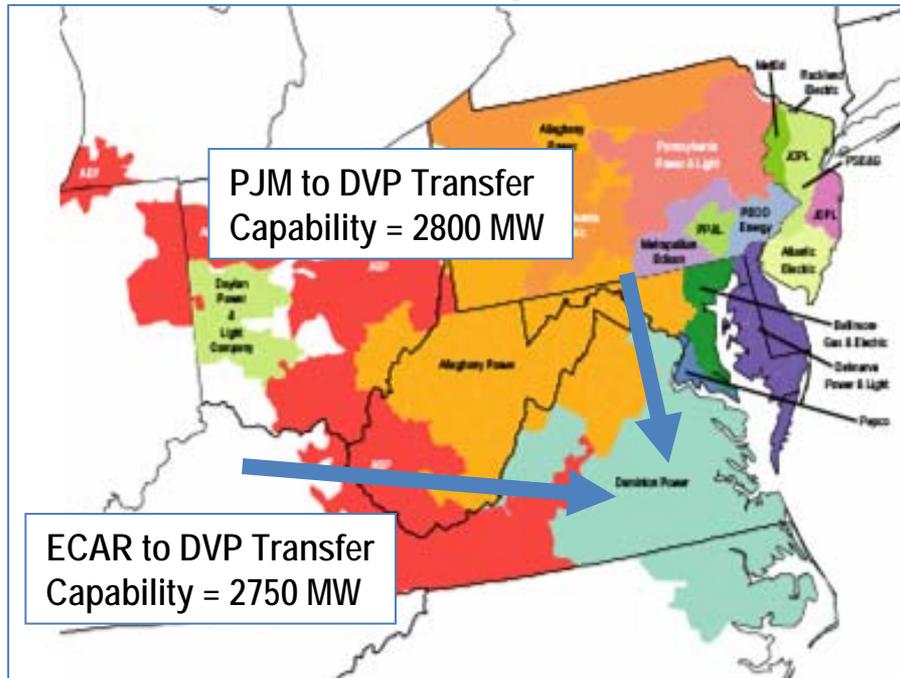
Referenced with Permission: Source: Erin T. Mansur and Matthew W. White, "Market Organization and Efficiency in Electricity Markets," March 31, 2009, Figure 2, pg 50, discussion draft, (available at <http://bpp.wharton.upenn.edu/mawwhite/>).

- Projected Benefit to Dominion Zone customers was \$291 to \$542 Million for Ten year period (2005-2014)¹
- Actual Benefit²
 - \$750 Million in avoided fuel costs for the four year period from May 2005 through May 2009
 - In 2008, measured benefit of \$240 Million in energy cost savings and \$90 Million in net FTR revenue

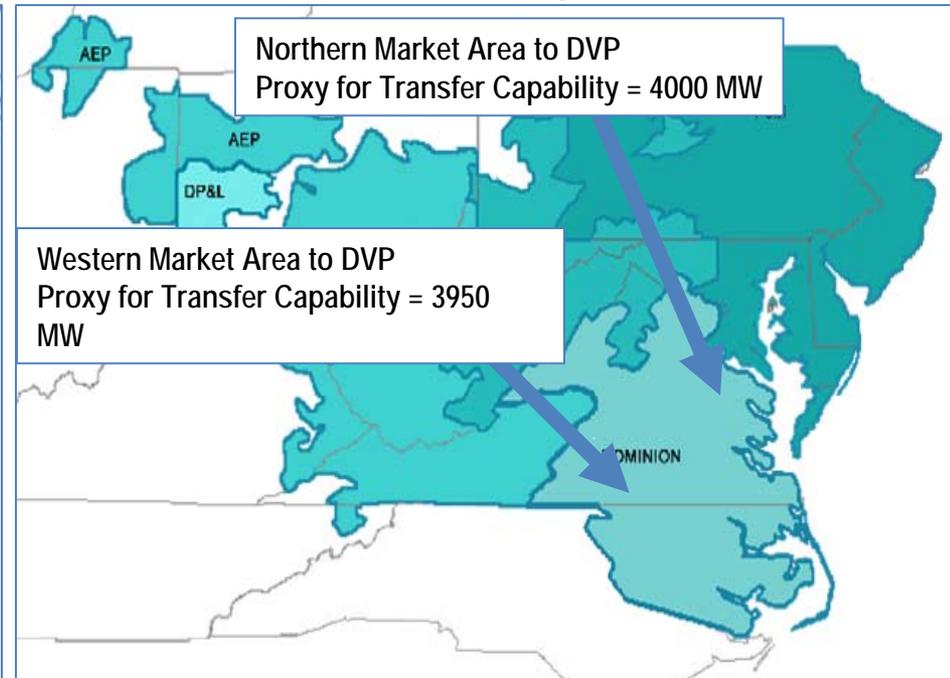
1. Dominion Study, Reported result in filing before VA State Corporation Commission, 2004

2. Greg Morgan, Dominion Executive, Testimony @ VA State Corporation Commission, June 2009

Prior to Integration



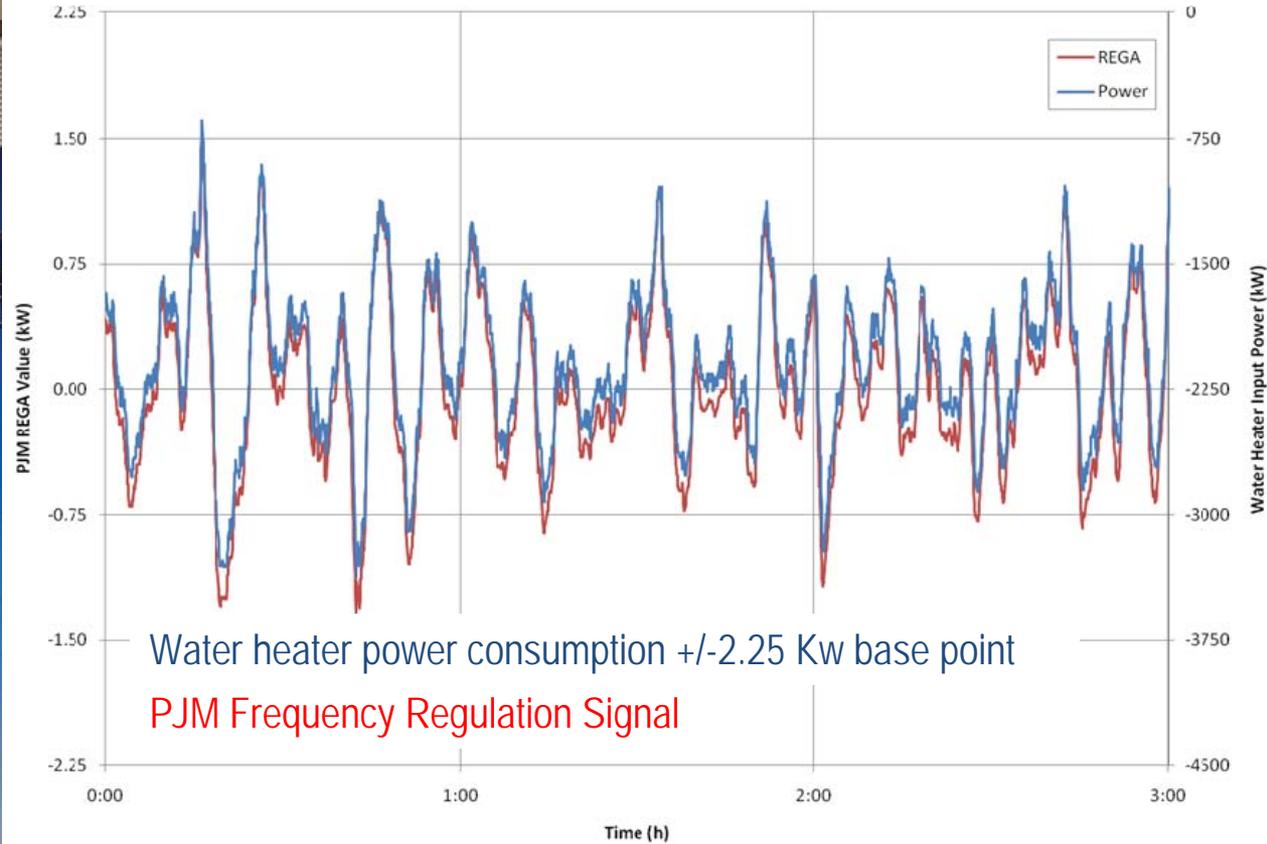
After Integration



- 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



Water Heater REGA Signal Following



105-gallon electric water heater demonstrates minimization of cost while responding to the PJM wholesale price signal and the PJM frequency regulation signal.

Laurel Mountain

Wind Farm

98 MW

61 turbines

Battery Storage

Lithium-ion (A123)

Power 32 MW, Energy 8 MWh

